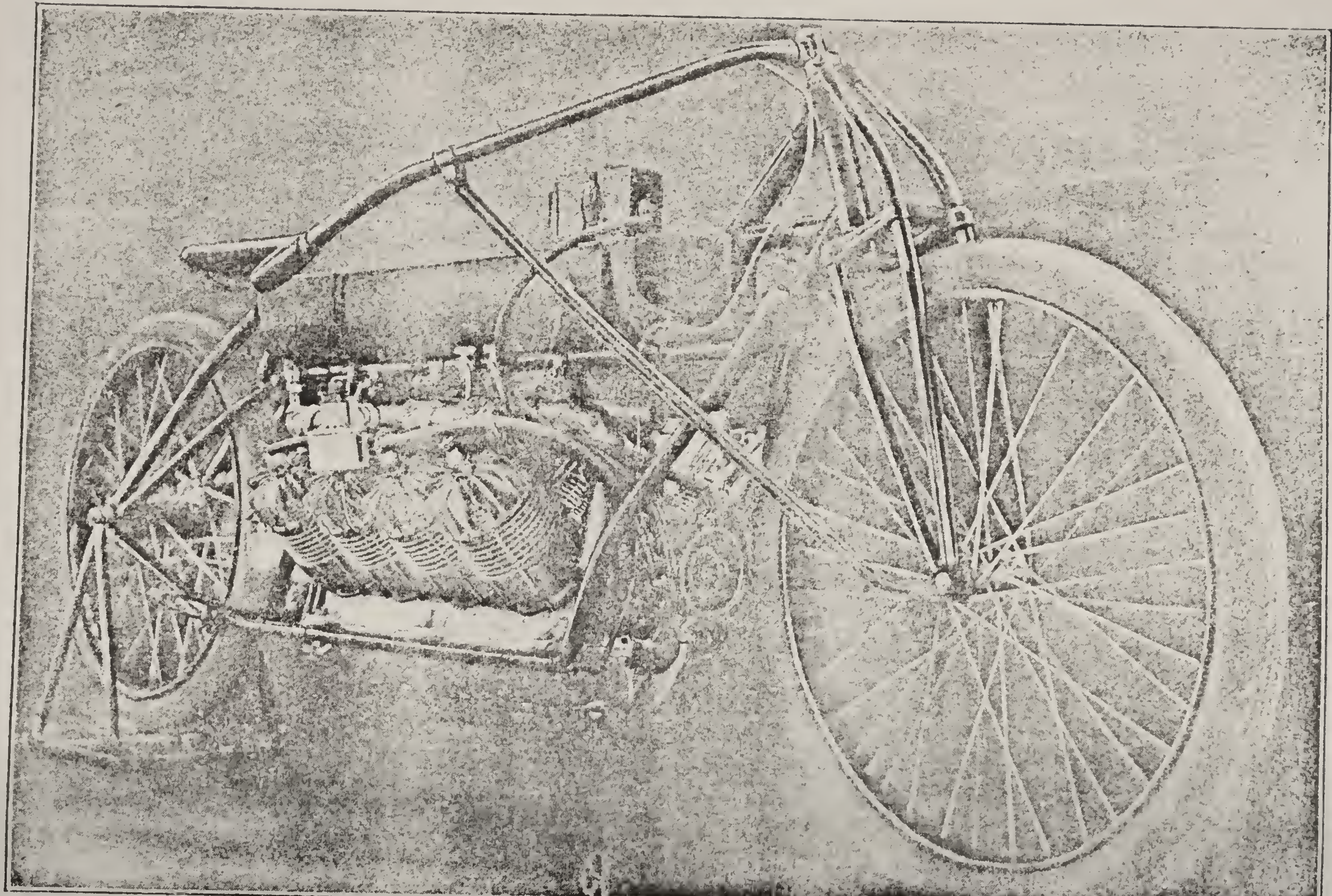

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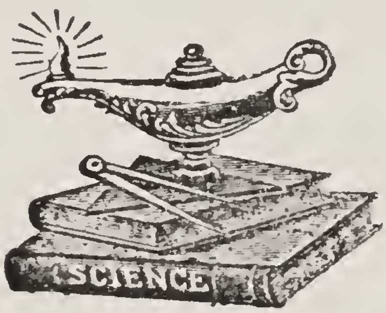

This Treatise contains over 350 Illustrations, for the most part reproduced from Engineering Drawings and Photographs of Actual Machines and Component Parts prepared by Leading Motorcycle Manufacturers specially for this work. This is the most valuable series of Drawings pertaining to Motorcycle Design and Construction ever published.

NEW YORK
THE NORMAN W. HENLEY PUBLISHING COMPANY
132 NASSAU STREET
1914

FIRST IMPRESSION

COMPOSITION, ELECTROTYPING AND PRESSWORK
BY MACGOWAN & SLIPPER, NEW YORK, U. S. A.

PREFACE

The growth of the motorcycle industry has been great during the past few years, and while it has not been as spectacular or imposing as that of its larger brother, the automobile business, it has reached proportions not generally realized except by those in the trade or the veteran riders. At a conservative estimate, several hundred thousand motorcycles are in service in this country, and the demand is increasing as the advantages and economy of this efficient motor vehicle are being better realized. The design and constructional features of the various makes are becoming standardized in some respects, though there is still considerable diversity in specific types. All follow certain rules of practice, however, and instructions for care and operation apply to all standard designs.

The automobilist has been very fortunate in having a large number of books available that cover all phases of motoring for his instruction, and everything desired in that field of knowledge, from deep technical discussions to elementary expositions, have been offered at modest prices. The motorcyclist, at the other hand, who desired a general treatise or instructions on motorcycle construction and operation, has been forced to acquire his knowledge by much research and reading because the books on motorcycling have been in the nature of elementary pamphlets rather than works of any pretensions.

The writer believes that there is a field for a comprehensive treatise dealing with motorcycles and allied subjects, and that some technical as well as practical information will not come

amiss, in view of the paucity of such facts relating to motorcycle, sidecar and cyclecar construction, operation and repair. Efforts have been made to discuss the salient points of representative domestic and foreign products and to show clearly the many mechanical points and distinctive constructions that abound in modern practice. The writer has been very fortunate in securing the co-operation of practically all leading manufacturers in the motorcycle industry, and many distinctive drawings and photographs have been furnished especially for his use.

While some technical information and data are given, the material, for the most part, is of a practical nature that can easily be assimilated and understood by anyone. The instructions given for control, maintenance and repair should be valuable for the novice rider, while the discussions of mechanical principles will undoubtedly appeal to the more experienced riders, dealers and others in the trade.

THE AUTHOR.

July, 1914

ACKNOWLEDGMENT

The writer wishes to express his appreciation of the valuable assistance offered and consideration shown by the following firms, who had sufficient belief in the distinctiveness and practicability of their product to welcome the light of publicity, and who went to considerable expense and inconvenience to furnish complete details, photographs and working drawings, showing important points of construction and design:

Hendee Manufacturing Company, Springfield, Mass.
Reading-Standard Company, Reading, Pa.
Sterling Motor Company, Brockton, Mass.
Harley-Davidson Motor Company, Milwaukee, Wis.
Excelsior Motor Manufacturing and Supply Co., Chicago, Ill.
F. W. Spacke Machine Company, Indianapolis, Ind.
New Departure Manufacturing Company, Bristol, Conn.
Enfield Cycle Company, London, England.
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F. E. Baker, Ltd., Birmingham, England.
Bowden Wire, Ltd., London, England.
Brown Brothers, Ltd., London, England.
Henderson Motorcycle Company, Detroit, Mich.
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Joerns-Thiem Motor Company, St. Paul, Minn.
Schickel Motor Company, Stamford, Conn.
Triumph Cycle Company, Coventry, England.
Bosch Magneto Company, New York City.

Credit is also due to *Motor Cycling*, an English publication, for a number of illustrations of foreign machines and components

and for complete fault-finding table included in last chapter; and to *Motor Life*, an American motoring print, for permission to republish an article prepared by the writer dealing with motorcycle troubles. Endeavor has been made to give suitable credit, either in the text or cut lines, for all other illustrations that were not made especially for this treatise. The photographs of foreign cyclecars and motorcycles are by M. Branger or Meurisse, of Paris, France, and were made especially for this work.

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Motorcycles, Side Cars and Cyclecars

CHAPTER I.

MOTORCYCLE DEVELOPMENT AND DESIGN.

Why Motorcycles are Popular—How Motorcycles Developed from the Bicycle—Some Pioneer Motorcycles and Influence on Present Design—Causes of Failures in Early Types—Mechanical Features of Early Forms—The Demand for More Power—Essential Requirements of Practical Motorcycles—Motorcycles of Various Types—Light-Weight vs. Medium-Weight Construction—Determining Power Needed—Influence of Road Surface on Traction—How Speed Affects power Needed—Effect of Air Resistance—How Gradients Affect Power Required—Power in Proportion to Weight—Influence of Modern Automobile Practice—The Modern Motorcycle, Its Parts and Their Functions—General Characteristics Common to all Forms—Some Modern Motorcycle Designs.

The motorcycle has been aptly termed the "poor man's automobile" and to one fully familiar with self-propelled vehicles, this term is no misnomer. The modern machine, with its ease of control, its reliability, its power and speed will carry one or two passengers more economically than any other method of transportation. Fitted with a side-car attachment, it becomes a practical vehicle for general use, as the body may be suited for passenger or commercial service. The demand for motorcycles, side cars and delivery vans has created an industry of magnitude that furnishes a livelihood for thousands of skilled workmen, and unmeasurable pleasure for hundreds of thousands who would be deprived of the joys of motoring were it not for the efficiency and low cost of operation of the vehicle that carries them swiftly and comfortably over the highways. The development of the motor bicycle dates back farther than that of the motor car, and it was demonstrated to be a practical conveyance over three decades ago, though it is only within the past six or eight years that this single-track, motor-propelled vehicle has attracted the attention its merits deserve.

Why Motorcycles are Popular.—The automobile attracted the attention of the public for some time before the motorcycle became generally popular, and, as a consequence, the development of the larger vehicle was more rapid for a time. As the early buyers of motor cars were of the class to which money is no object, as long as personal wishes are gratified, most of the manufacturers then building bicycles, to whom the public naturally looked for motorcycles, devoted their energies and capital to the design and construction of automobiles rather than motorcycles, because the prospect for immediate profits seemed greater in catering to the great demand that existed for any kind of automobile that would run at all. The development of the motorcycle was left to people, for the most part, without the requisite engineering knowledge or manufacturing facilities, so, naturally, the growth of the industry was of little moment until an equally insistent demand made itself felt for motorcycles, at which time people with capital began to consider the production of two-wheeled vehicles with favor. The demand for bicycles had been diminishing for several years, and the new type, with motor attached, seemed to offer a field that could be cultivated to advantage.

The evanescent popularity of the bicycle and the rapid rise to almost universal use, with almost as rapid decline was construed as a warning to proceed slowly in building motorcycles, as many thought the future of the motorcycle would be doubtful and that it was merely a passing fad. The bicycle required the expenditure of considerable energy, and, while very valuable as an exerciser, it did not offer pleasure enough for the bulk of our population in proportion to the amount of effort involved in making trips really worth while. The application of mechanical power, however, removed that objection, so the only deterring factor to the ready adoption of the motor-propelled bicycle was a lack of confidence on the part of the public regarding its reliability. It was not long before the endurance and practicability of the motorcycle was established beyond doubt, and as soon as the advantages began to be given serious consideration, a healthy demand, which is growing in importance yearly, stimulated its development from a crude makeshift to a practical and safe method of personal transportation.

The motorcycle and its various combinations with fore cars and

side cars appeals to a conservative element who consider the cost of maintenance and operation fully as much as the initial expense of acquiring it. The motorcycle really has many fundamental advantages to commend it, as it has the speed and radius of action of the most powerful motorcar, with a lower cost of upkeep than any other vehicle of equal capacity. As constructed at the present time, the motorcycle is not only low in first cost, but its simplicity makes it an ideal mount for all desiring motor transportation at the least expense. The mechanism of the motorcycle, its control and repair, are readily understood by any person of average intelligence, and with the improved materials and processes employed in its manufacture, combined with the refinement of design and careful workmanship, a thoroughly practical and serviceable motor vehicle is produced which sells at but a slightly higher price than the first high-grade safety bicycles of fifteen years ago. At the present time, the motorcycle is not only popular for pleasure purposes, but it is applied to many industrial and commercial applications that insure a degree of permanency in popular estimation never possible with the bicycle.

How Motorcycles Developed from Bicycles.—Many of the mechanics who turned their attention to motorcycle construction were thoroughly familiar with bicycle practice of the period and, as considerable progress had been made in building light machines that possessed great strength for foot propulsion, it was but natural that the regular form of diamond frame bicycle should be adapted to motor propulsion by the attachment of a simple power plant and auxiliary devices. As a concession to mechanical power, various parts of the machine, such as the front forks, the rims and tires, and in some cases the frame tubes were made slightly heavier, but in essentials the first motorcycles to be made commercially followed bicycle practice, and with power plant removed, it would be difficult to tell them from the heavy built tourist models of pedal cycles. Naturally, the motor and tanks were not always disposed to the best advantage, and for considerable time, as the writer will show, much thought was spent in endeavoring to combine the widely varying principles found in bicycle and motorcycle practice and devise a hybrid machine composed of all the parts of the ordinary bicycle, with the various components of the gasoline or internal combustion power plant disposed about the frame

at any point where attachment was possible. The motorcycle of the present day follows automobile principles and is radically different from its earlier prototypes in practically every respect except a general family resemblance owing to the use of two wheels, handle bar control, pedals for starting and placing a saddle so the rider can keep his balance to better advantage by sitting astride as on the bicycle.

Some Pioneer Motorcycles and Influence on Present Design.—As early as 1885, Gottlieb Daimler, who constructed the first practical high-speed internal combustion engine, and who, for this reason,

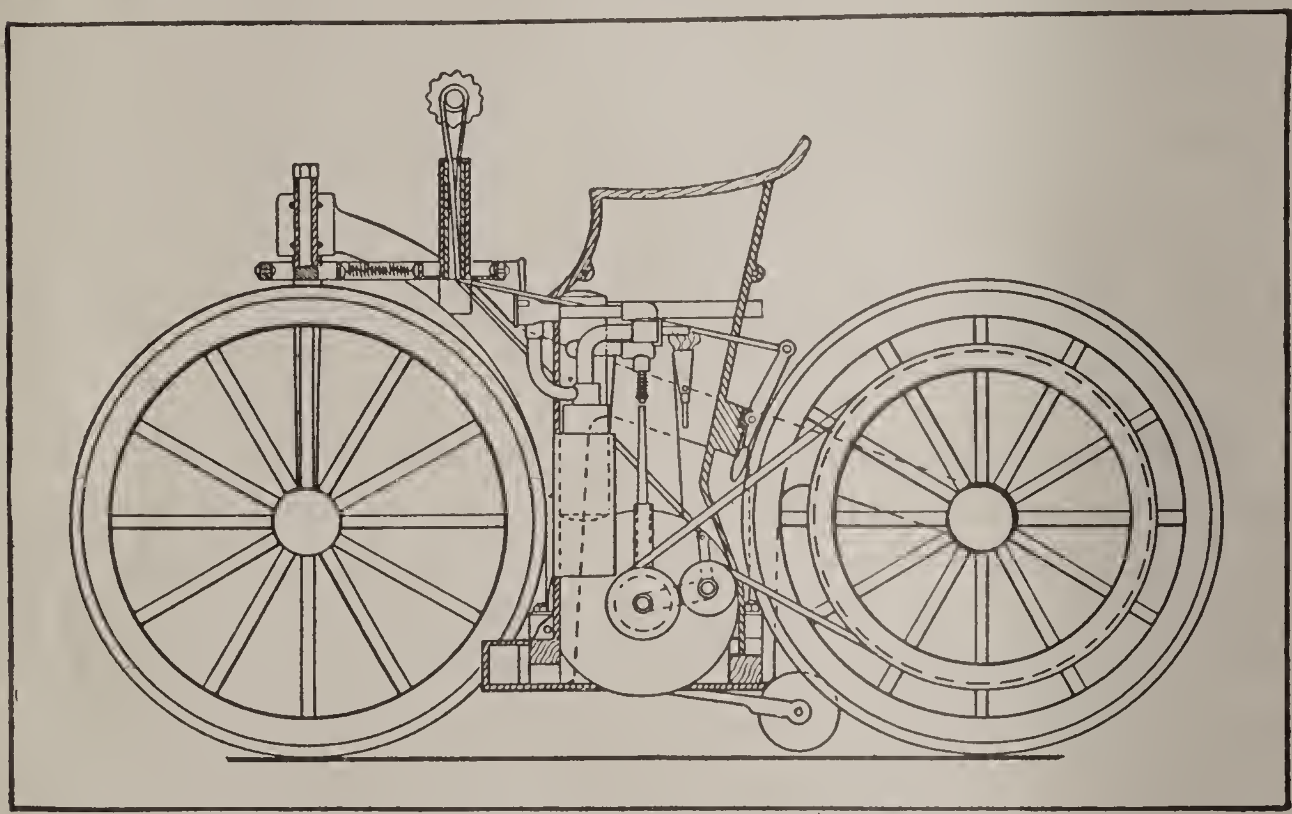

Fig. 1.—Early Model of the Daimler Motorcycle, the Parent of All Present Day Self-Propelled Vehicles.

is known as "the Father of the Automobile," obtained a patent on a two-wheel vehicle shown at Fig. 1. This, while not beautiful in outline, was a practical motor-propelled conveyance, and may be justly regarded as the forerunner of the modern motorcycle. In fact, in general arrangement of parts, this pioneer design is not unlike the modern product. At that time, the only motor vehicles regarded as practical or capable of actual operation for limited distances were types propelled by electric or steam power, and it will thus be apparent that Daimler's crude motor bicycle was not only the founda-

tion of the motorcycle industry but also formed a basis for the development of the automobile which, in its most successful form, employs the internal combustion motor as a source of power.

After numerous designs in which single cylinder motors played a part, in 1889, Daimler patented a double inclined cylinder motor, the first multiple cylinder conception. This original form is that from which the modern V-engine, so widely used at the present time for cycle propulsion, was derived. This creation was also the first to be made in any considerable number and, even at this late day, some of the original Daimler engines are still operated. In this design, the cylinders were inclined but 15 degrees, and eccentric grooves turned in the fly-wheel face were utilized to operate the exhaust valves, instead of the cam motion which is now common. The cylinder was cooled by an enclosed fan wheel which supplied a current of air confined around the cylinder by a jacket, so the first practical high-speed internal combustion engine was cooled by air. This is the method used almost universally in the case of the bicycle motor, even at the present day.

After a time other motors appeared, such as the De Dion moto-tricycles, propelled by a small engine based on Daimler lines, and which were more reliable than the first steam coaches and much superior to the early electric vehicles in all important essentials such as radius of operation, cost, reliability and speed. To Daimler must also be given credit for the invention of the first practical carburetor, or device to produce a combustible gas from liquid fuel, also an important factor in the development of the automobile.

The first Daimler machine, which is shown at Fig. 1, with one side of the frame removed, was not unlike the modern loop-frame machine in important respects. While the wheels were placed rather close together, the motor placing was intelligently thought out, and was so installed that the center of gravity was brought closer to the ground than in many of the machines which succeeded it. The drive from the pulley on the motor crankshaft to a larger member on the rear wheel and the use of a jockey pulley or belt tightener to obtain a clutching effect has not been altered in principle since its first application by Daimler. Steering was accomplished by a steering head construction practically the same as on present-day machines. The

early form of Daimler motor did not have very much flexibility on account of the sluggish action of the vaporizer and the ignition by hot tubes so the speed was varied largely by allowing the driving belt to slip and by applying the brake. This was done by a controller wheel carried by a standard just in front of the operator's seat. When this was rotated in one direction, the jockey pulley or idler was allowed to drop, so that the belt became loose while a spoon brake, working on the rear wheel tire, was applied progressively as the belt tension was diminished, and consequently the driving power was reduced.

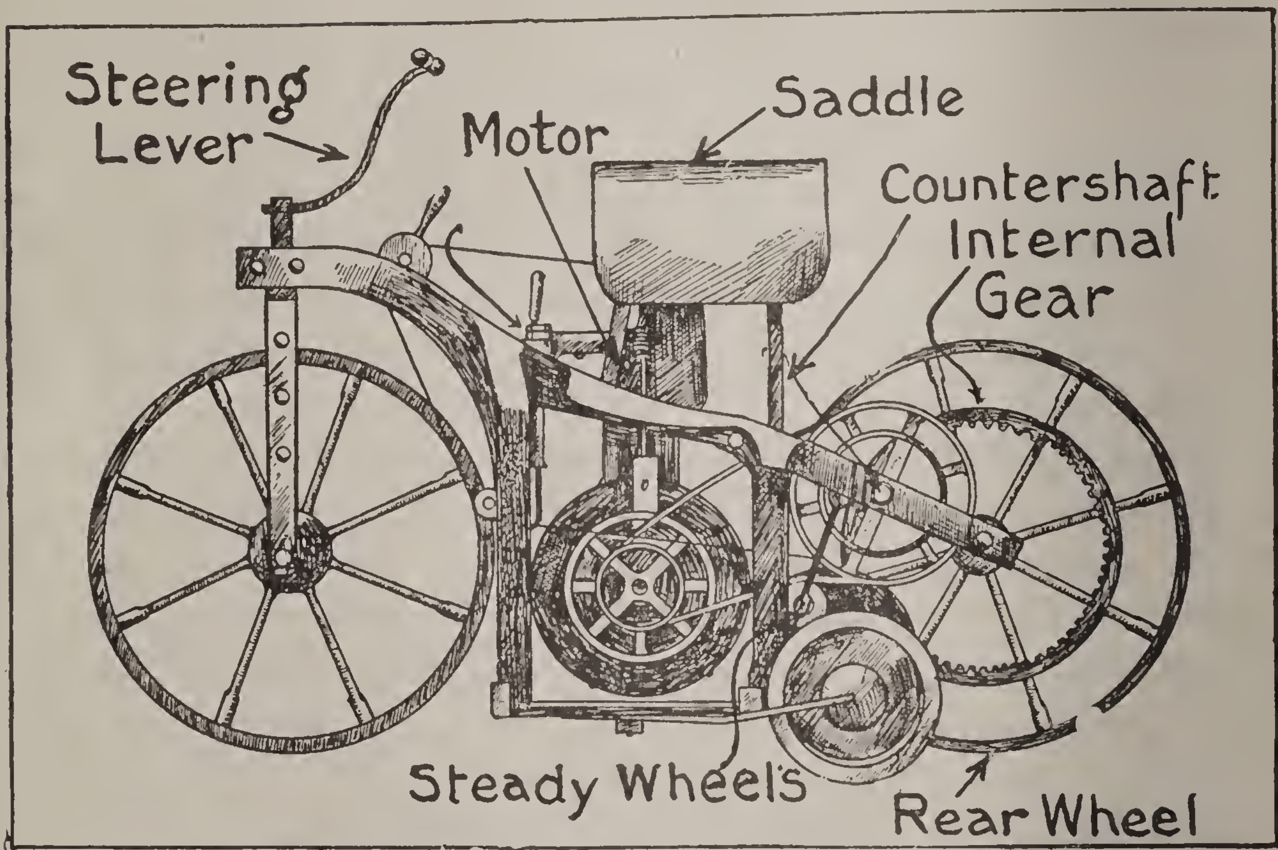

Fig. 2.—Early Daimler Motorcycle With Countershaft Drive.

A later form of Daimler bicycle, in which a countershaft was used, is shown at Fig. 2. The drive from the motor crankshaft to a pulley comprising one member of the countershaft assembly was by belt while a small spur gear provided a further reduction in speed by engaging an internal gear attached to the rear wheel spokes. It will be evident that Daimler not only originated the direct drive motorcycle but that he was also responsible for the first conception of the countershaft drive form. Attention is directed to the use of the auxiliary wheels mounted on each side of the rear driving member to

steady the machine and keep it upright when not in motion. The lines of either of the Daimler machines are not unlike the forms we are familiar with, and the resemblance is striking enough, so that the parentage of the modern motorcycle can never be questioned. Daimler, as well as Carl Benz, who was working on a motor-tricycle at the time the former brought out his engine, next directed his energies to the improvement and construction of motor-propelled vehicles of the three- and four-wheel forms instead of the two-wheeler. Although there were spasmodic efforts made by some engineers in motorcycle design, most of them confined their efforts in refining the bicycle, which at that time was just beginning to attract attention because it offered possibilities of almost universal application.

Among the next of the pioneer motor bicycles to attract attention was another German make, shown at Fig. 3. This was constructed by Wolfmueller & Geisenhof, of Munich, Germany. In ordinary appearance it resembled the conventional bicycle design intended for the use of women though the machine had exaggerated dimensions. The saddle was placed low so that the rider could rest his feet on the ground if he desired. The power plant was a peculiar form which was said to develop two horse-power, and which was capable of propelling the 110-pound machine at speeds ranging from three to twenty-four miles per hour. The motor was of the two-cylinder horizontal form having the cylinder heads at the front of the machine while the open ends of the cylinders pointed to the rear. The connecting rods extended to cranks attached to the rear wheel axle, and the drive was direct from the motor cylinders to the traction member as in locomotive practice. Ball-bearings were used at the ends of the connecting rod as well as supporting bearings for the rear wheels. The fuel gas was obtained from a vaporizer of the surface type and the compressed charge was ignited by hot tubes. The cylinders were water-cooled and were surrounded with water jackets, and a supply of water for cooling the engine was carried in a peculiarly shaped tank forming part of the mud-guard over the traction member. The front wheel was used for steering and was mounted in forks in much the same manner as in the machines of to-day. A hand-lever actuated-spoon brake served to retard the speed of the vehicle when desired by frictional contact with the front tire. Both wheels were provided with

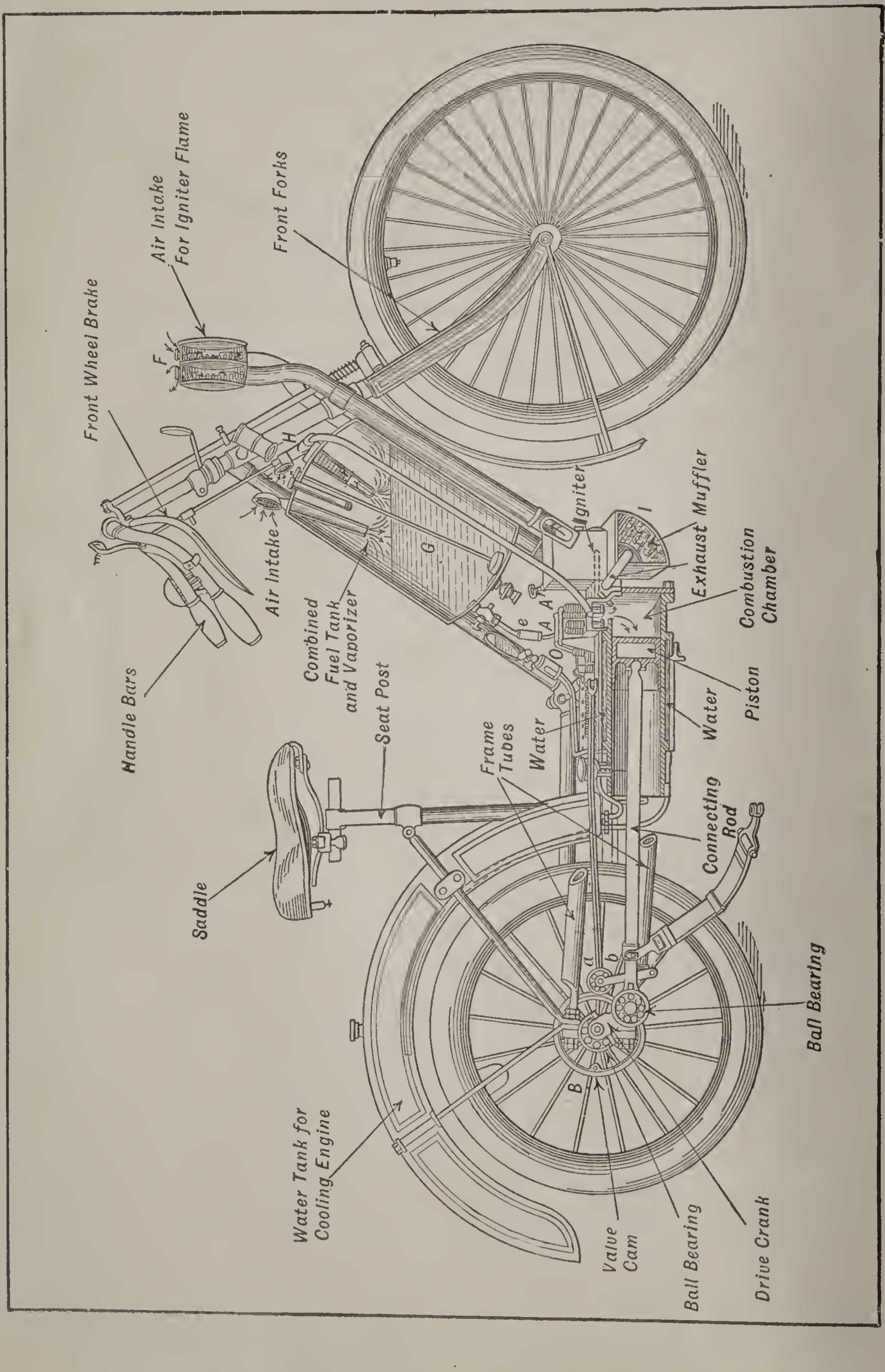

Fig. 3.—The Wolfmueller Motorcycle, an Early Form of Unconventional Design.

pneumatic tires. The engine cylinders were $3\frac{9}{16}$ inches in diameter with a stroke of $4\frac{5}{8}$ inches. The driving wheel was 22 inches in diameter while the front wheel was 26 inches in diameter. It is claimed that the fuel supply was sufficient for a run of 12 hours.

One of the earliest of the De Dion-Bouton tricycles is shown at Fig. 4. This had the small air-cooled motor placed back of the rear axle which it drove by suitable gearing. In order to obtain the desired speed reduction, a small spur pinion was mounted on the motor crankshaft which meshed with a large spur gear attached to the differential case. In the tricycle shown, the gasoline vapor was produced by a surface carburetor, and ignition was by hot tube. The machine was provided with pedals and it was possible to drive the

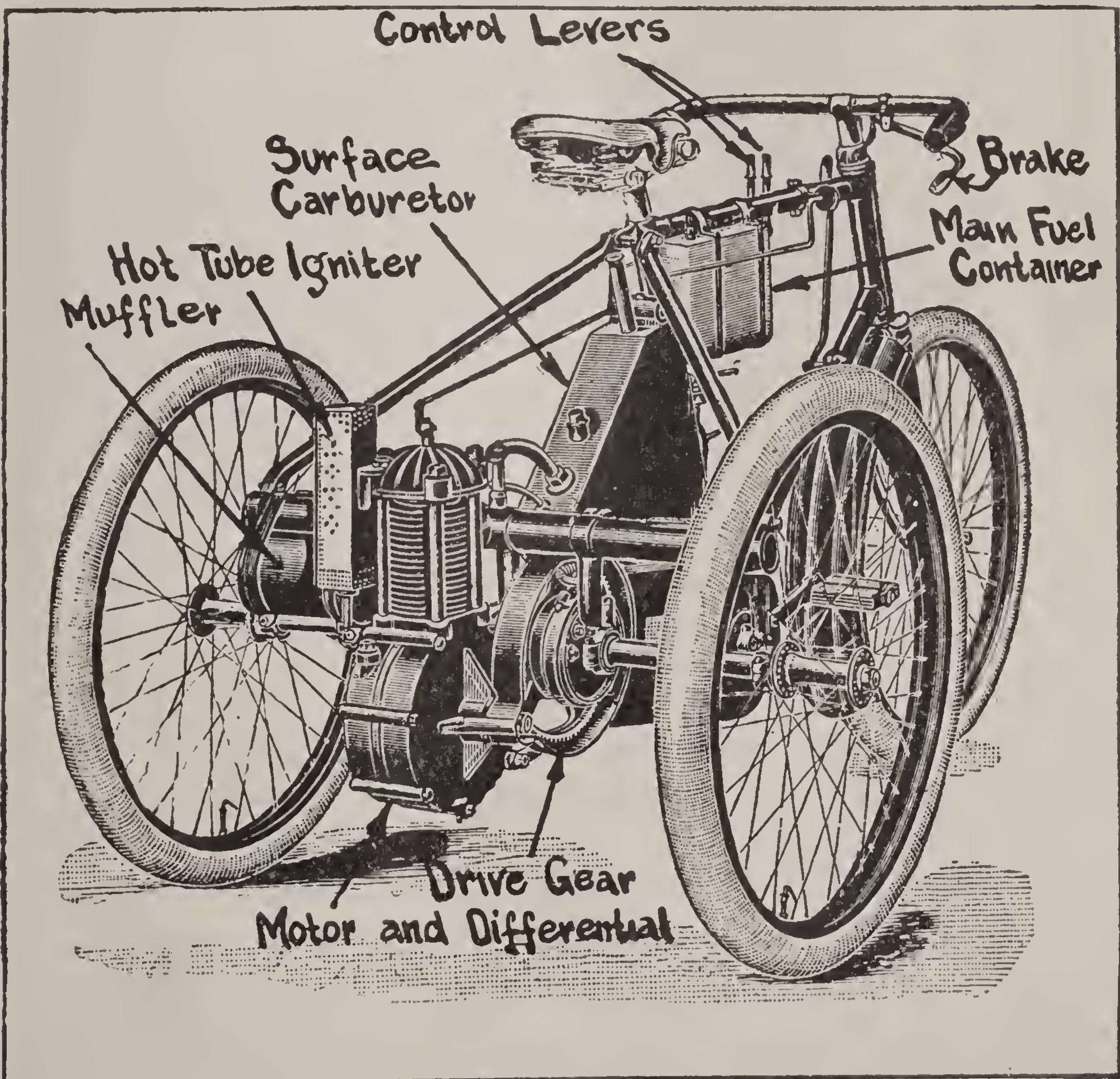

Fig. 4.—One of the First De Dion-Bouton Motor Tricycles.

rear axle by an independent foot-actuated sprocket and chain when desired. This made it possible to set the tricycle in motion by pedaling, and was also intended to provide a means of returning home when the motor became inoperative, which was not an infrequent occurrence. Owing to the limited power of the motor, which was rated at about 1¾ horse-power, the rider often found the pedals of some benefit as an aid to climbing steep grades. Some of these tricycles were converted into four-wheelers or quadricycles, as shown at Fig. 5, by the addition of a fore carriage which provided accommodations for a passenger. A later form of motor tricycle, in which electrical ignition

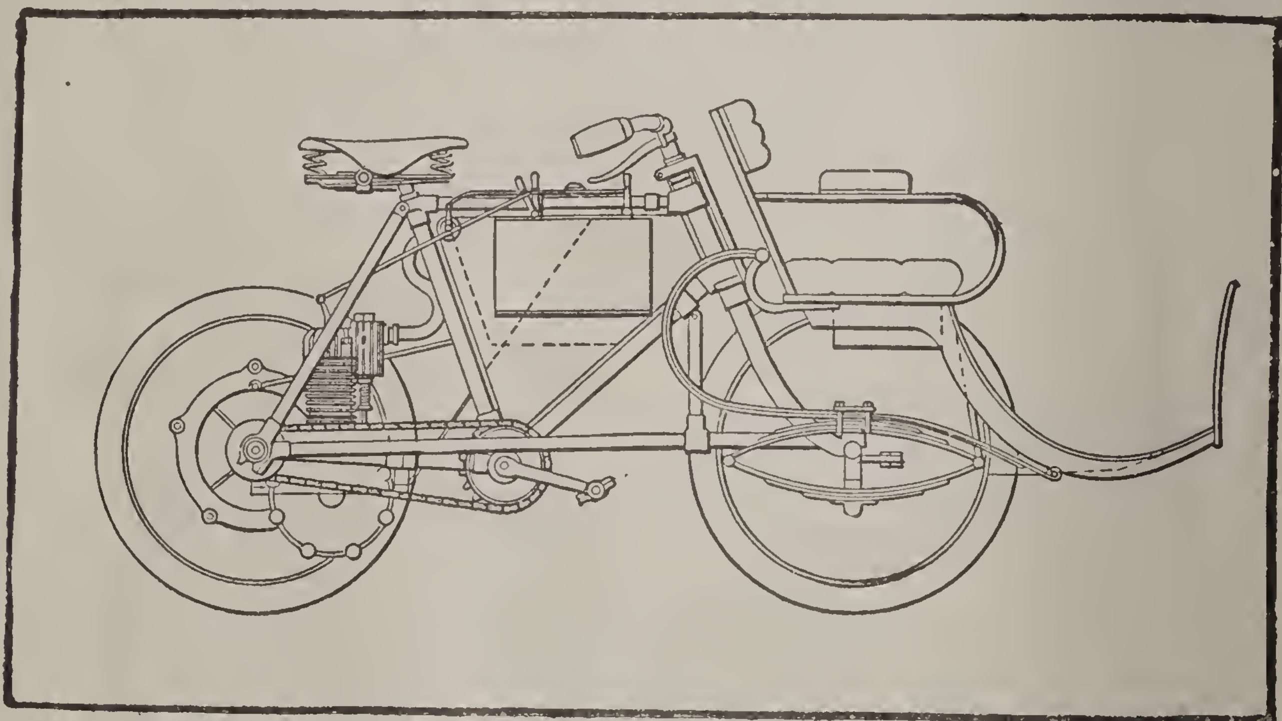

Fig. 5.—Motor Tricycle With Two Wheel Fore Carriage to Carry Passenger.

replaced the hot tube method, is shown at Fig. 6. By careful study of this side view and the rear end shown at Fig. 4, it will not be difficult to understand the construction of the earliest form of motor tricycles to be used successfully.

All of the pioneer designers did not devote their attention to tricycle construction, as some carried on experiments with the two-wheeled forms. One of the ingenious efforts to adapt the safety bicycle to motorcycle service is shown at Fig. 7. The power plant, which included a small gasoline engine with its auxiliary devices was mounted on a fixed axle at the center of the rear wheel, and remained

stationary while the wheel revolved around it to drive the bicycle. Owing to the limited amount of space provided for the power plant, which meant that an engine of small power only could be used, this form of construction did not prove as practical as those in which the motor and its auxiliary devices were attached to the frame.

One of the problems that confronted the pioneer designer was the proper location of the power plant. The diversified designs in which the early designers attempted to solve this problem are clearly shown at Fig. 8. At *A*, an early form of De Dion motor bicycle is shown in

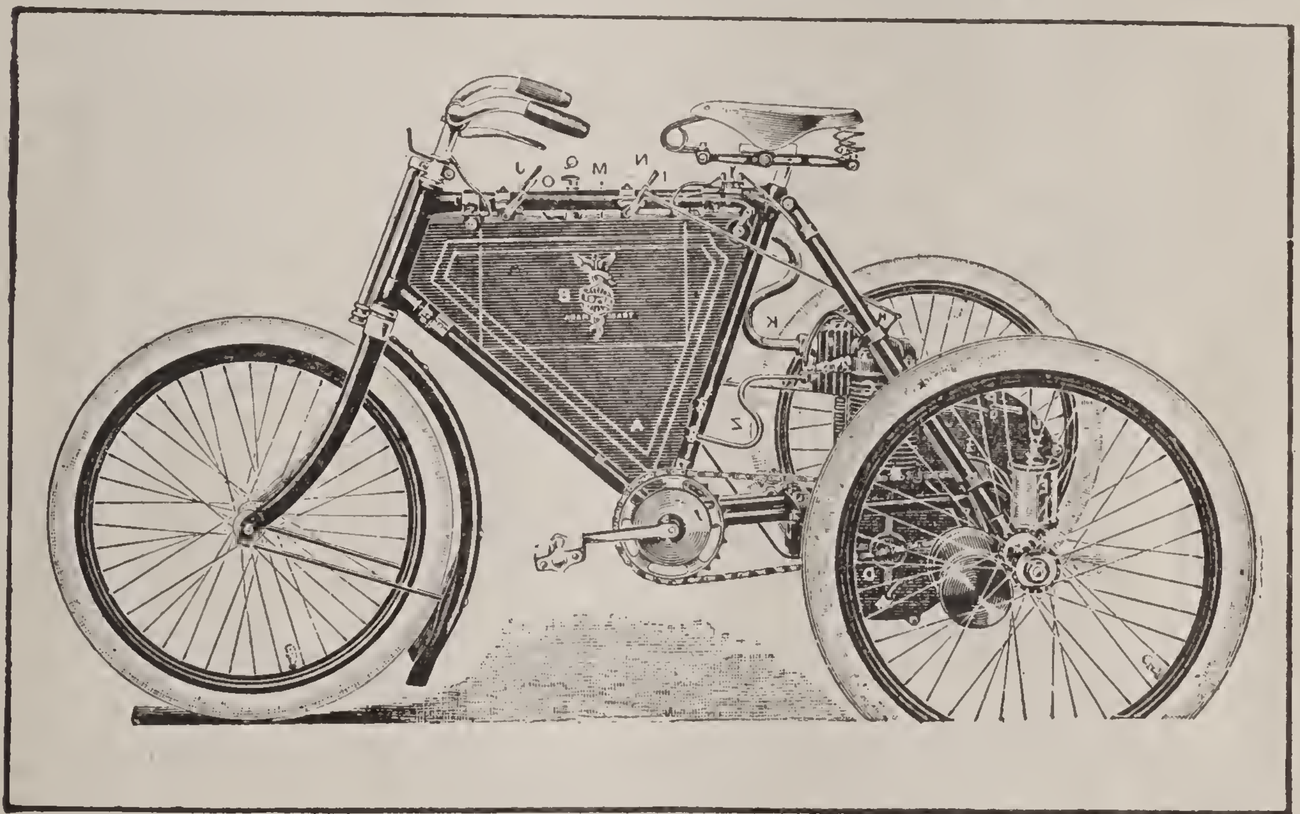

Fig. 6.—Side View of the Ariel Motor Tricycle, a Pioneer Form Using Electrical Ignition.

outline, and in order to obtain a low center of gravity, the power plant was placed back of the seat-post tube and crank hanger while the crank case was attached to the rear-fork stays. In the machine shown at *B*, which was known as the "Pernoo," the motor was placed on extended stays behind the rear wheels and drove that member by direct belt connection. Another motorcycle which was brought out about this time is shown at *C*, and was designed by a man named Werner. In this construction, the motor was carried on an extension of the front-fork crown, and the object desired by the inventor was to

permit one to convert an ordinary bicycle into a motorcycle by the addition of the modified front forks to which the engine was attached. Power was transmitted by means of a belt from a small pulley on the motor crankshaft to a larger member attached to the wheel. It is apparent that the designer had in mind an equal distribution of the load on the two wheels in the construction shown at *A*. In both the forms, shown at *B* and *C*, the weight was not distributed as it should be, as in one case practically all of the weight came on the rear wheels, which made steering difficult, while in the other, the proportion of the weight carried by the front wheel was productive of skidding at the rear end when the machine was used on wet roads. The machines

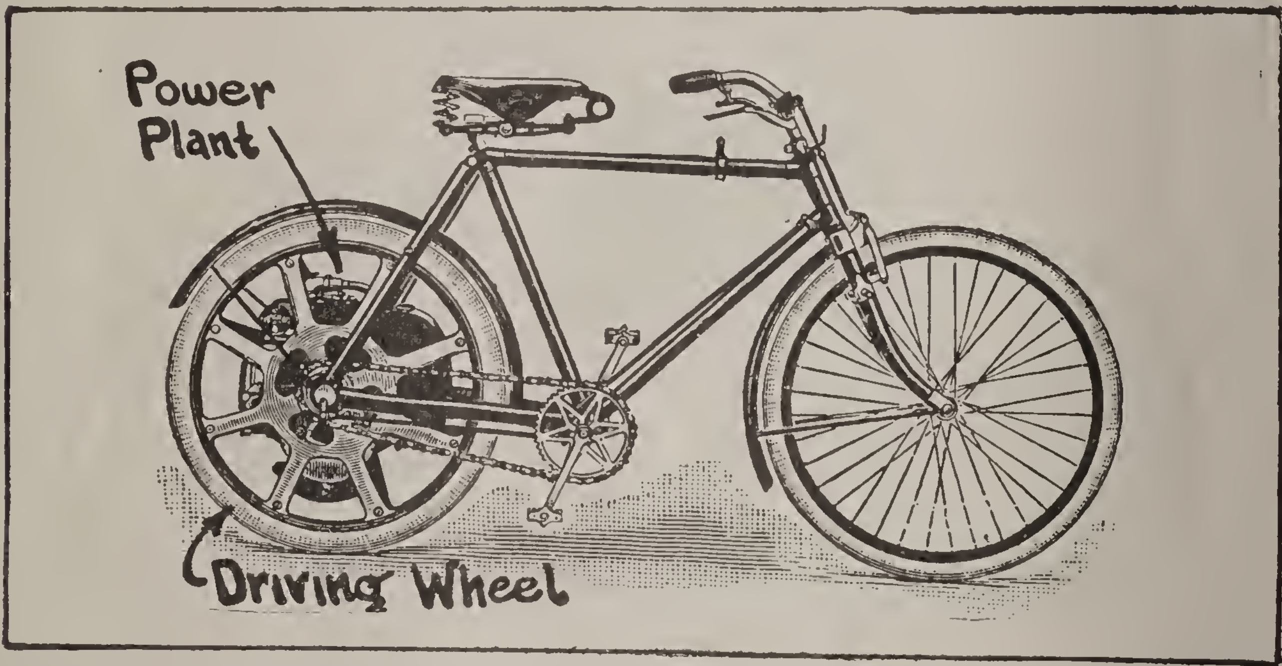

Fig. 7.—Early Motorcycle Design With Power Plant Enclosed in Interior of Rear Wheel.

shown were evolved in the period ranging from 1894 to 1898, and were adaptations of the diamond frame safety bicycle, which at that time had been demonstrated to be a thoroughly practical vehicle.

During this period, American inventors were by no means idle. In 1898, Oscar Hedstrom, an expert constructor of light racing bicycles, turned his attention to the design and construction of motor-propelled tandems which were used in bicycle racing as pacemakers. His products were very successful, and their consistent performances on the track, as well as the speed developed, attracted the attention of George M. Hendee, who owned a large interest in the Springfield

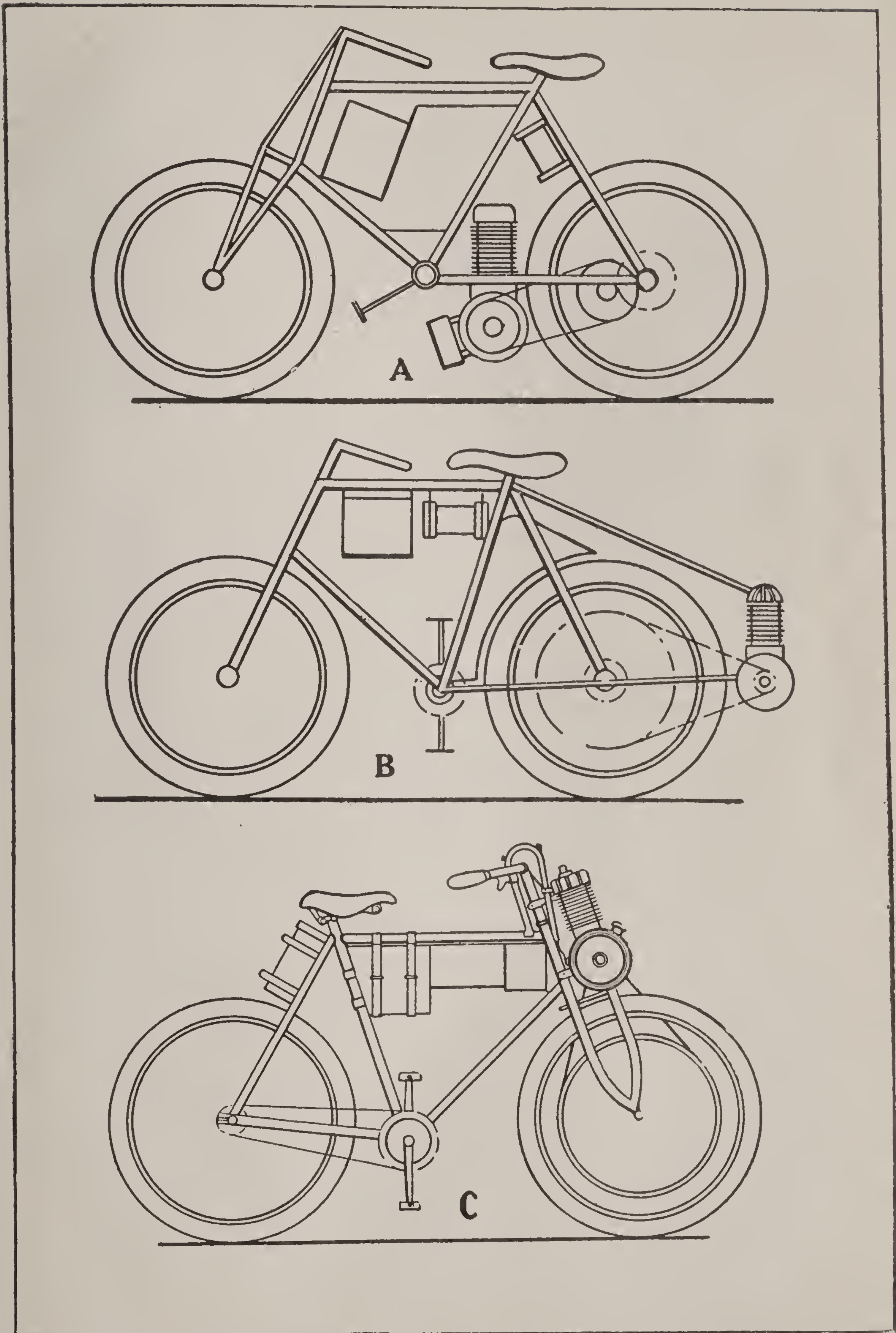

Fig. 8.—Some Early Designs of Motorcycles Showing Diversity of Opinion Regarding Placing of Power Plant and Auxiliary Devices.

Coliseum, a very prominent bicycle race-track of the period. Mr. Hendee, who was engaged in building bicycles, determined that there would be a great future for the motorcycle if a satisfactory machine for roadwork could be evolved. Negotiations began between Messrs. Hendee and Hedstrom, and in January, 1901, Mr. Hedstrom became associated with the Hendee Manufacturing Company, and the development of the Indian motorcycle began. It is said that in four months' time, he not only designed the model machine, but built every part of it with his own hands. Many of the original features incorporated in the first Indian machine are retained in the modern forms, and have not been changed in principle since used on the pioneer creation built thirteen years ago.

The earliest Indian motorcycle to be manufactured in quantities is shown at Fig. 9, with all parts clearly outlined. The general lines of the diamond frame bicycle were followed in this as in other early forms, though a decided innovation was made by placing the motor in the frame in such a position that it formed a continuation of the seat-post tube, which was attached to the top of the cylinder. The motor crankcase was supported by the crank hanger which was located at approximately the same position as in bicycles intended for foot propulsion. This permitted the inventor to dispose of the auxiliary parts of the power plant so that the bicycle lines were not interfered with to any extent. The gasoline tank was mounted over the rear wheel and was partially supported by the mud-guard, while a smaller container between the rear forks and the seat-post tube served as a reservoir for the lubricating oil used in the engine. The carburetor was designed by Mr. Hedstrom, and with but few changes and refinements in minor detail, is used to-day, and is considered to be one of the most efficient of the many vaporizers used on motorcycles. The drive from the motor crankshaft was to a large sprocket, carried by a countershaft extending from the crank hanger, and this, in turn, imparted motion to a smaller sprocket which drove the rear wheel through the medium of a chain connection with a sprocket on the rear wheel hub, which was a modified form of bicycle coaster brake.

Ignition was by battery and spark coil, and control of the power plant was obtained by varying the time of ignition and regulating the

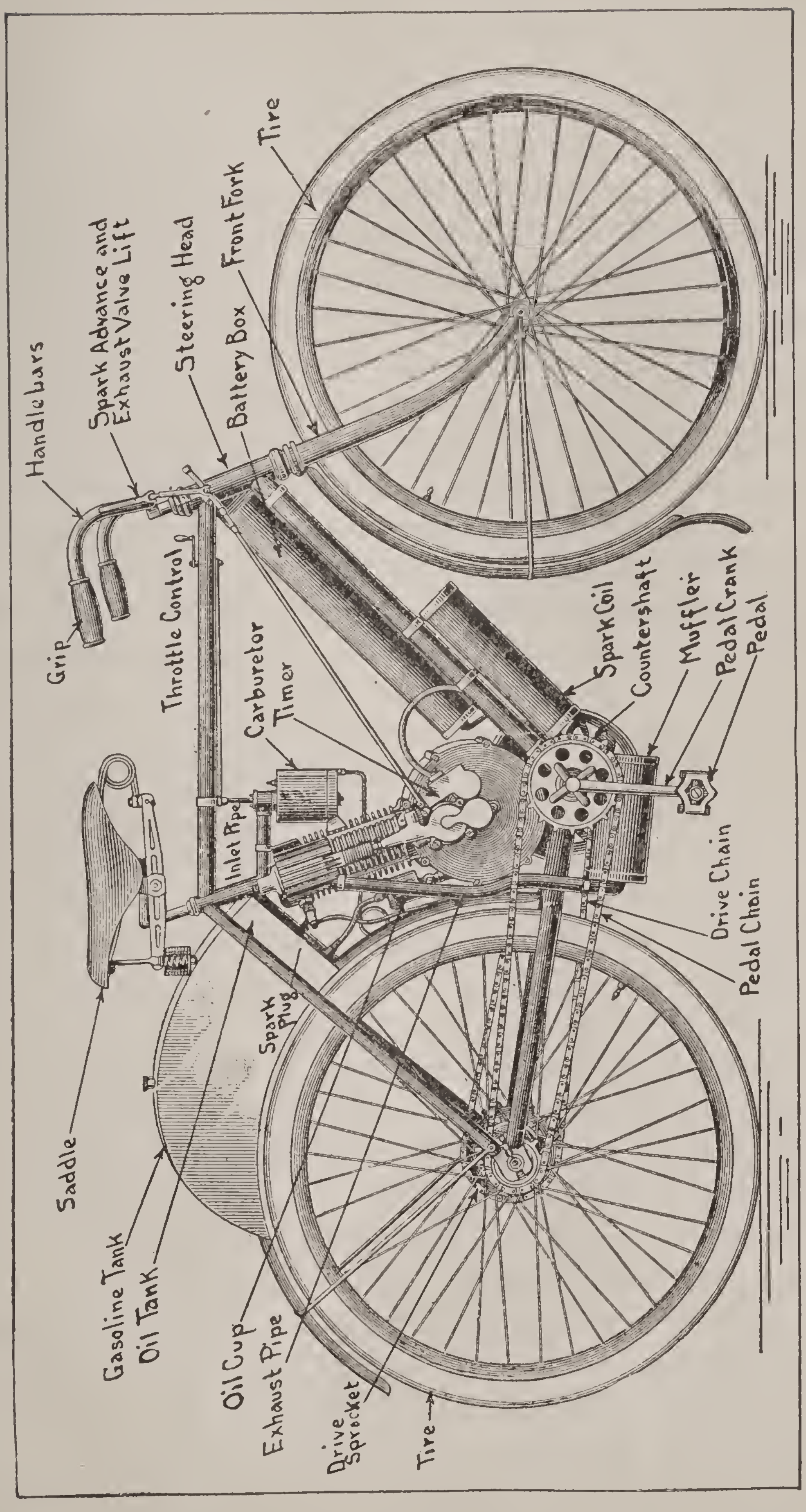

Fig. 9.—The First Indian Motorcycle to be Produced in a Commercial Way.

supply of gas admitted to the carburetor in much the same way as on modern machines.

A feature of even the earliest Indian model was ease of control, as while other contemporary manufacturers were producing machines having levers at all points of the frame, the Indian had the grip control that is now famous and almost universally used in America. By turning the grip on the right hand side of the handle-bar in one direction, it was possible to raise the exhaust valve so that the engine would be inoperative, while a twist in the other direction allowed the exhaust valve to close, thus permitting the motor to function, and a further movement advanced the ignition timer to speed up the engine. While throttle control on the early form of machine shown was by a small crank attached to the top frame tube near the steering head, it was not long before the left grip was also used in controlling the motor by being attached to the carburetor throttle. Owing to the excellence of the Hedstrom motor and carburetor, the neatness of design and the ease of control, the Indian motorcycle was eagerly accepted by the public, and the American motorcycle industry was fairly under way.

It must not be inferred that no other successful American machines were built at this time because there were quite a number of practical motorcycles evolved by other bicycle firms. Four of the early types are outlined at Fig. 10, and as the general construction and location of parts is clearly shown it will not be necessary to describe these machines in detail. This applies equally as well to the types shown at Figs. 11 and 12. A point that will strike the observant reader is the diversity of ideas as relates to power plant installation, as opposed to the very general acceptance of one method of installation at the present time. For instance, in the group at Fig. 10, the Thomas and Holley machines have the motor mounted with the cylinder center line coinciding with that of the seat-post tube, while the Orient and the Mitchell had the motor placed well forward in the frame with the cylinder inclined toward the steering head instead of toward the rear of the machine. In every case, the drive was by means of belts. In the Thomas, a combination steel and leather belt was used, while in the other three forms flat belts were employed. Two of the machines, the Mitchell and the Orient, did not use belt idlers or jockey pulleys, while the Thomas and the Holley found the idler pulley of sufficient merit to

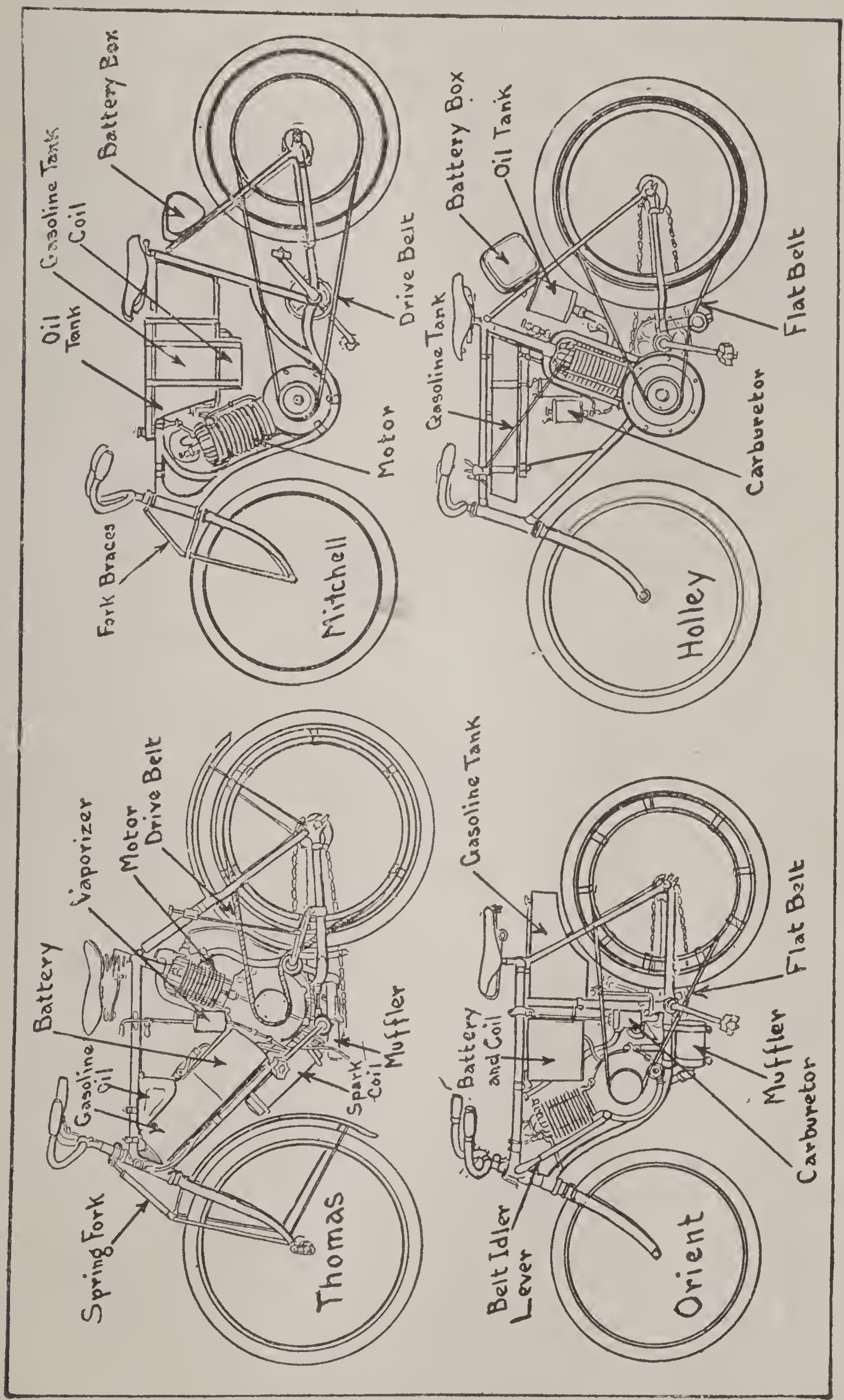

Fig. 10.—Examples of Early American Motorcycle Design, All of Which Were Manufactured on a Commercial Scale.

incorporate it in their construction. We find the same diversity of practice in the motorcycles shown at Fig. 11. In two of these, the Merkel and the Yale-California, the motors had the cylinder inclined toward the steering head, while the other two, the Pope-Columbia and the Marsh, utilized the opposite placing of the power plant. In the Columbia machine, the motor was carried back of the seat-post tube, while in the Marsh, the cylinder formed a continuation of that member. The general trend of former constructors to belt drive as opposed to the present tendency in the other direction is also clearly shown in this group, as but one of the machines, the Pope, utilized the double chain drive which is now the leading form of power transmission.

At the top of Fig. 12 is depicted a machine that in many respects resembles the accepted types of the present day. This was designed by Glenn Curtiss, now a famous aviator and builder of aerial craft. In this, the motor was placed with the cylinder vertical instead of inclined as in all the other machines shown. The business-like disposition of the auxiliaries, such as the gasoline tank, battery box, muffler, carburetor, the long wheel base and the general neat appearance of the machine are all commendable. The only thing needed to make this early form of machine an equal in appearance and performance to those of the present day was the addition of magneto ignition. The Wagner machine, which is shown in the center of the plate, incorporated for many years a distinctive form of frame construction, inasmuch as a separate loop member to carry the motor was added below the lower frame member of the conventional diamond frame. The Royal machine was also distinctive owing to the ingenious manner in which the power plant was housed in a nest formed by four tubes branching from the seat-post tube to the crank hanger. The Royal machine was also distinctive in the system of drive employed, because, while practically all of the contemporary machines, with the exception of the Pope and Indian, utilized belt drive, this employed a countershaft speed reduction and chain drive to the rear wheels. Instead of employing a sprocket and chain reduction, as did the Pope and the Indian, the drive from the motor crankshaft to the countershaft and the main reduction in speed was through spur gearing. A single chain served for both motor and pedal drive, as an ingenious clutching

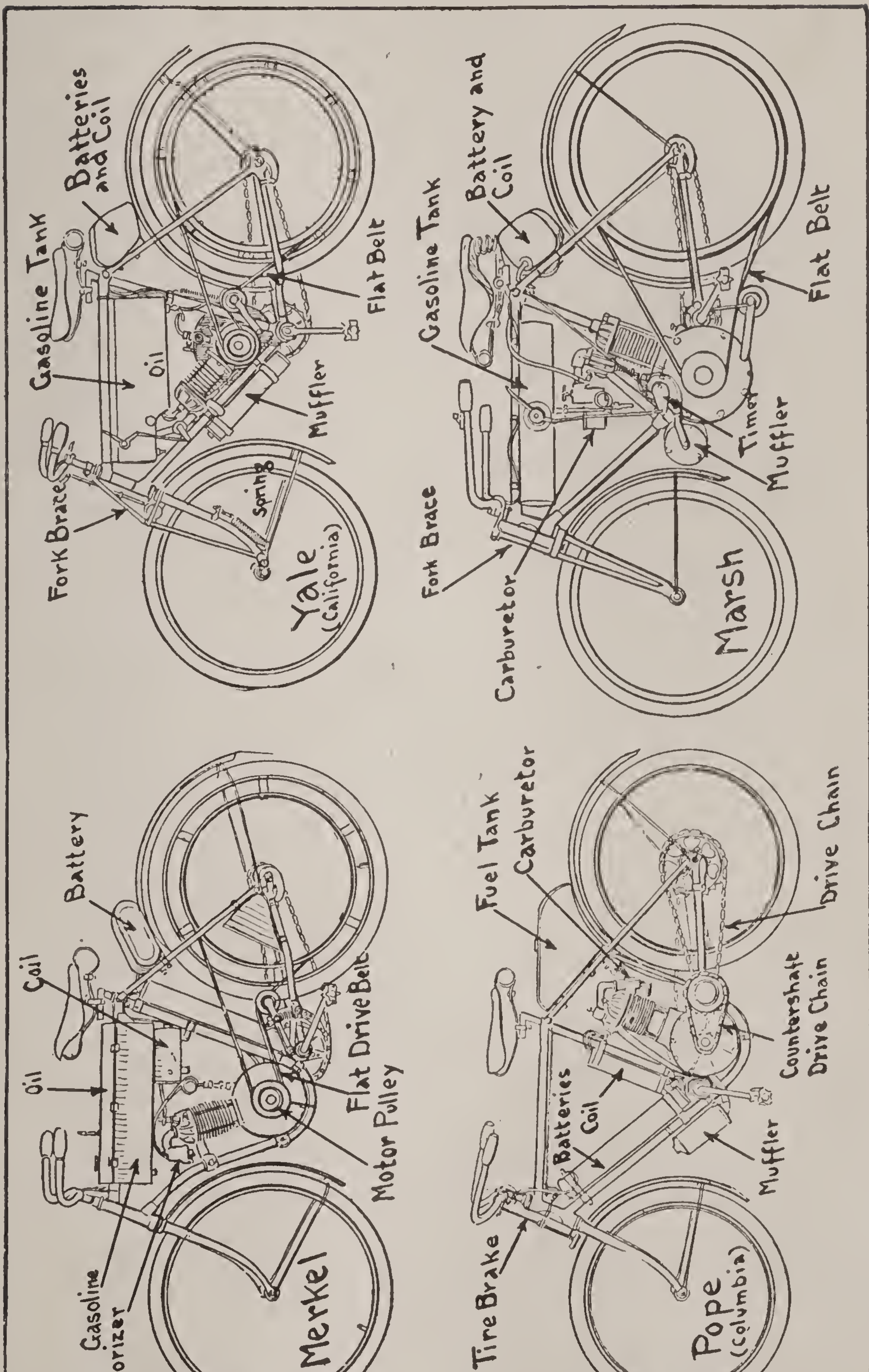

Fig. 11.—Some Early American Motorcycles Which Show a Wide Diversity of Opinion Regarding Essentials of Design Which are Standardized at the Present Time.

arrangement was provided by which the pedals could be brought into engagement for propelling the machine and starting the motor, and then the drive was taken by the same chain from the motor crankshaft, and the pedals automatically uncoupled by an overrunning clutch.

Another form of machine developed by American engineers, which was called the "New Era," on account of the number of advanced features incorporated in its design, is shown at Fig. 13. This was one of the first American machines to furnish a two-speed gear as regular equipment, and to substitute foot-boards instead of the usual form of pedaling gear. As the pedals were eliminated, it was not necessary to supply a seat of the usual form which is needed to permit the rider to pedal a machine when starting, and a more comfortable form seat, very much of the same nature as used in agricultural machinery, was provided for the rider. This seat was supported by springs, and as it conformed to the figure it proved to be very comfortable. The motor, which was a single-cylinder type was placed directly under the form seat, and the planetary two-speed gear was located on the engine shaft. The high and low-speed clutches were controlled by foot levers conveniently disposed on the running board, while another pedal provided control of the band brake acting on the rear wheel. The form shown was one of the earlier models in which ignition was by battery and coil, but other machines were made of more modern form employing a magneto. The fuel tank was carried over the rear wheel, as was common practice on many machines of that period and the drive was by single chain direct from the driving sprocket on the motor crankshaft to a larger member on the wheel. This machine was evidently too far in advance for its time, as the riders did not seem to take kindly to its unconventional lines which forced the company manufacturing them out of business. It is interesting to note that in this early form of machine, we find incorporated so many of the improvements and refinement usually associated only with machines of the present day.

The Demand for More Power.—When the first attempts were made to convert the bicycle into a motorcycle by the addition of a power plant, it was the intention of many of the constructors of the early types of machines to depend to some extent upon the rider to

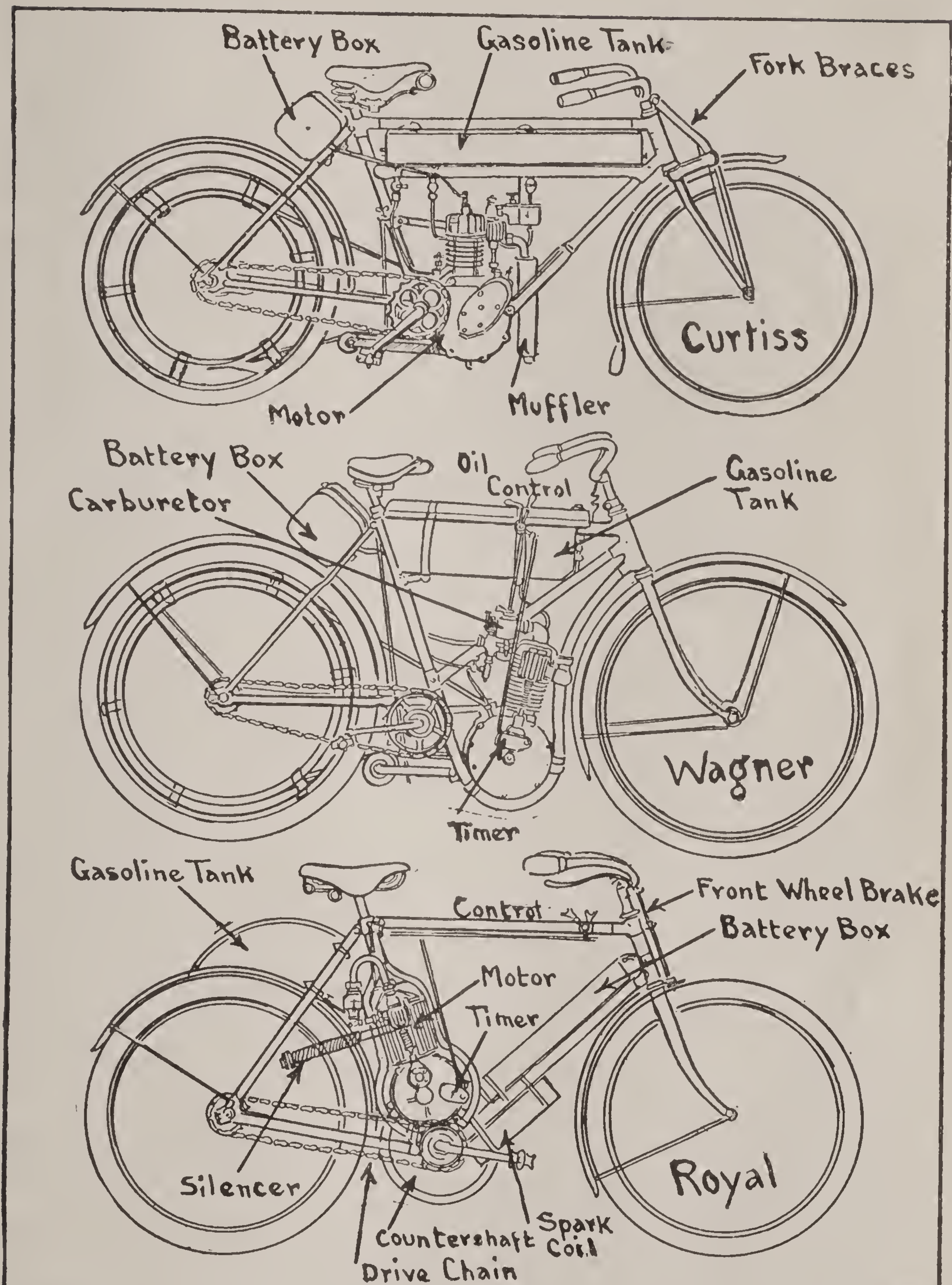

Fig. 12.—Some Pioneer Forms of American Motorcycles That Were Successfully Used Under Actual Service Conditions.

assist the motor at times when the resistance to motion was too great to be overcome by the small power plant provided. In order not to stress the frame tubes of the usual bicycle construction too much, the gasoline motors employed were of extremely low power, when judged in the light of our present day knowledge. Many of the successful motors were not over 1.25 horse-power, and a machine with a power plant rated at 2.50 horse-power was considered to be much heavier and more powerful than was absolutely necessary. The method of figuring the horse-power required on the early machines was very simple, as it was assumed that if a man, who was commonly given a rating of one-eighth to one-twelfth of a horse-power could propel a bicycle satisfactorily, and attain fair speed, that a motor of one and one-quarter horse-power should certainly prove sufficiently powerful to take the machine anywhere the rider wanted to go. Of course, it was not considered a serious disadvantage if one was forced to assist the motor up a moderate hill or over a stretch of sandy road by vigorous pedaling.

It did not take the early rider or motorcycle manufacturer long to discover that a frame structure that was entirely suitable for a foot-propelled machine was not necessarily strong enough to withstand the vibrations imposed by mechanical power. This vibration came, not only from the nature of the prime mover employed but was also due, in a measure, to the increased speeds made possible by the application of mechanical energy. As it was obviously necessary to increase the weight and strength of the frame to take care of the added stresses, it was also important to augment the power proportionately. Another factor that made it necessary to install more powerful motors was the demand for speed that soon became manifest after the machines had been mastered by their riders. To one not accustomed to motorcycling, a speed of 20 or 25 miles per hour was very fast, but after the first few rides had been taken, and the rider had confidence in his machine and ability to control it, many sought for machines having greater power, and consequently more all around ability. This demand was met by the manufacturers, and the horse-power of motorcycle power plants has increased over 800 per cent., as on makes that formerly utilized one and a quarter to two horse-power motors a decade or so back, we find on the modern forms

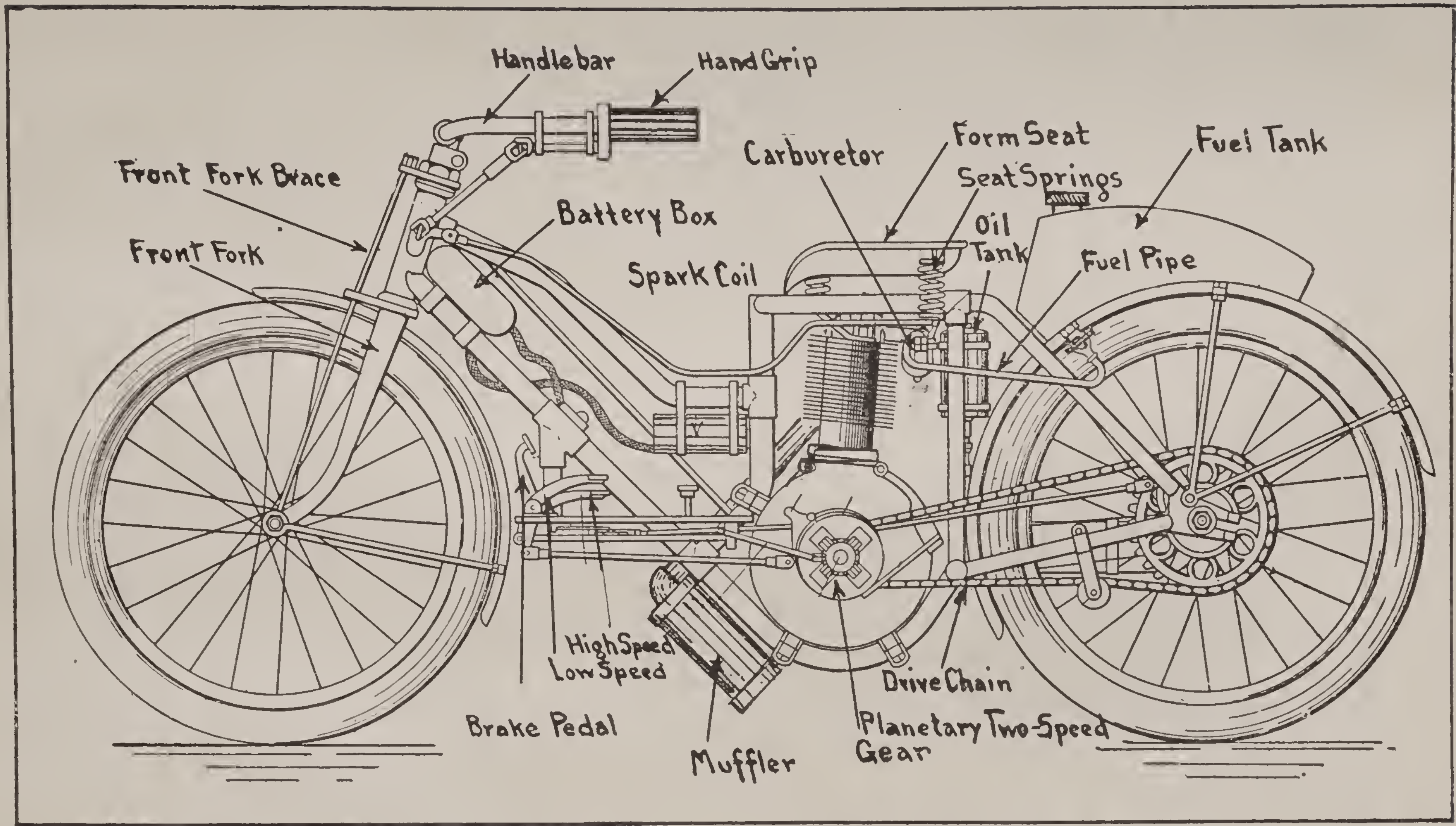

Fig. 13.—The New Era Motorcycle, One of the First American Touring Models to Use a Two Speed Gear and to Dispense With the Usual Pedaling Mechanism. A Design That Was Ahead of Its Time.

powerful motors which are capable of easily developing 12 to 15 horse-power.

Essential Requirements of Practical Motorcycles.—Before describing the parts of motorcycles, their functions or features of construction, it may be well to review a few of the essentials that are necessary in the practical motorcycle.

First, the machine should not only be simple and strong in construction but it should have a soundly designed and well-made framework as well as a powerful motor. The power plant should be so installed that it may be easily reached for inspection and the various components should be so accessibly located that any of the parts liable to give trouble can be reached without dismantling the entire machine. Most designs of the present day embody this important requirement.

Second, every provision should be made for the comfort and safety of the rider. This means that the saddle should be placed so a low riding position obtains in order that the rider may be able to put his feet on the ground to steady himself when necessary. Comfortable foot-rests or foot-boards should be provided in addition to the usual pedaling mechanism, and all the control levers should be placed conveniently so the rider may reach them, preferably without removing his hands from the handle-bars.

Third, the modern machine should be provided with wheels and tires of ample size, and should also include some form of spring fork and resilient frame construction to absorb vibration and to relieve the rider of all road shocks. The machine should not only be provided with an efficient power transmission system but should also include adequate brakes.

Fourth, the weight should be so distributed that the center of gravity, even with the rider in position, should come as near the ground as possible, in order to promote stability, and the load carried should also be proportioned so that the traction or driving wheel will carry more than the front or steering wheel. The machine should also be fitted with some method of free engine control so that the power plant may be kept running even if the machine must stop as in traffic. While a two-speed gear or other variable speed mechanism is the most desirable, it is not absolutely necessary, as very good results have

been obtained with machines having a free engine clutch or its mechanical equivalent.

Fifth, the pleasure and convenience of the rider should be given some consideration, as, in addition to comfort and safety, it is desirable to make operation of the machine as simple as possible. For example, some form of automatic or mechanical oiling system is much to be preferred to the usual hit or miss oil pump system of lubrication. A fairly capacious fuel container should be provided in order to insure a reasonable touring radius. An efficient muffler should be provided so that the machine will be silent in operation. The machine work on the engine, and the fitting of the various parts, should be accurately done so the power plant will retain oil and the machine be a clean one to handle. A fairly long wheel base and large wheels are fully as desirable as the use of spring forks or frames to secure easy riding. The proportion of power to weight should be such that an actual surplus of power is held in reserve under normal operating conditions for use in any emergency.

Practically all of the essential requirements enumerated can be found in modern machines, though the average purchaser would be guided to a large extent in selecting a mount by a number of personal preferences, and it cannot be expected that any one type of machine will satisfy all riders.

Motorcycles of Various Types.—Three forms of power have been successfully adapted to vehicle propulsion, and among the many diversified types of automobiles we find some propelled by gasoline engines, while others depend upon the energy derived from a steam boiler or electric battery. While either of the three main forms of prime movers may be used in a practical way on motor cars, attempts that have been made by motorcycle designers to adapt steam or electric power to the two-wheel vehicle have rarely met with success. The electric motorcycle is impractical on account of the weight of the storage battery necessary to produce power, and also because its radius of action and possible speed would be limited. Some early inventors adapted the electric battery to the propulsion of three-wheelers or tricycles, and it was not very long ago that an announcement was made that an electric motorcycle would soon be available. To date, this promise has not been realized, and it is difficult for one

to see how electric power could be applied to advantage on a two-wheeler and obtain the same desirable features that are so easily secured by the use of the gasoline motor.

Some experiments were tried in this country to apply steam power to motorcycles, but none of these ever proceeded far beyond the experimental stage. In England, however, there is a steam-propelled motorcycle that is not radical in appearance and which must be a commercial success because it is said that it has been on the market for three years. The drawing at Fig. 14 shows the general appearance of this machine which is known as "the Pearson and Cox," presumably because it is made by this firm in Shortlands. Despite the unconventional means of propulsion, this motorcycle is not so much different than those we are accustomed to that it would attract attention except of those well versed in motorcycle construction.

The power is supplied by a single cylinder, single-acting steam engine with a bore of 1¾ inches and a stroke of 2½ inches. This is mounted in the frame back of the seat-post tube and immediately in front of the rear wheel. The power plant is supported by the rear forks. The engine is given a nominal rating of 3 horse-power, but it is said that the boiler has capacity enough to furnish steam pressure sufficiently high so the engine will generate 6.50 horse-power. The power is delivered to the rear wheel through the medium of a single roller chain which connects sprockets mounted on the engine crankshaft and on the rear wheel hub. Owing to the fact that the steam power is always in reserve and that the steam engine may be put in motion by simply opening a throttle valve, it will be evident that no clutch or variable speed gear is necessary. When climbing hills, one merely admits more steam to the engine cylinder and its power is increased proportionately as the steam pressure is augmented.

The water is converted into steam in a flash boiler which is a coil composed of about 65 feet of pipe heated by the burner flame. The boiler is called a "flash generator" because as soon as water is pumped into the coil by the plunger pump driven from the engine for that purpose, it is converted instantaneously into steam having the high pressure of 1,000 pounds per square inch, and a temperature of 800 deg. Fahr. As the pump that supplies the water to the flash coil is driven directly from the engine, the amount of water supplied and

consequently the steam generated is proportional to the demands of the engine. At very low speeds, when the steam consumption is small, a by-pass valve opens so some of the steam passes back into the water tank and is condensed into water. This valve is controlled from one of the grips on the handle-bar. The boiler, or rather, steam generator is located directly under the front diagonal frame tube and is protected from dirt by a liberal sized mud-guard on the front wheel. The whole of the diamond of the usual type camel-back frame is filled by the water and fuel container. In order to prevent waste of water which would make frequent refilling of the tank necessary, the exhaust steam is condensed by a suitable device and is pumped back into the water tank where it is used over again.

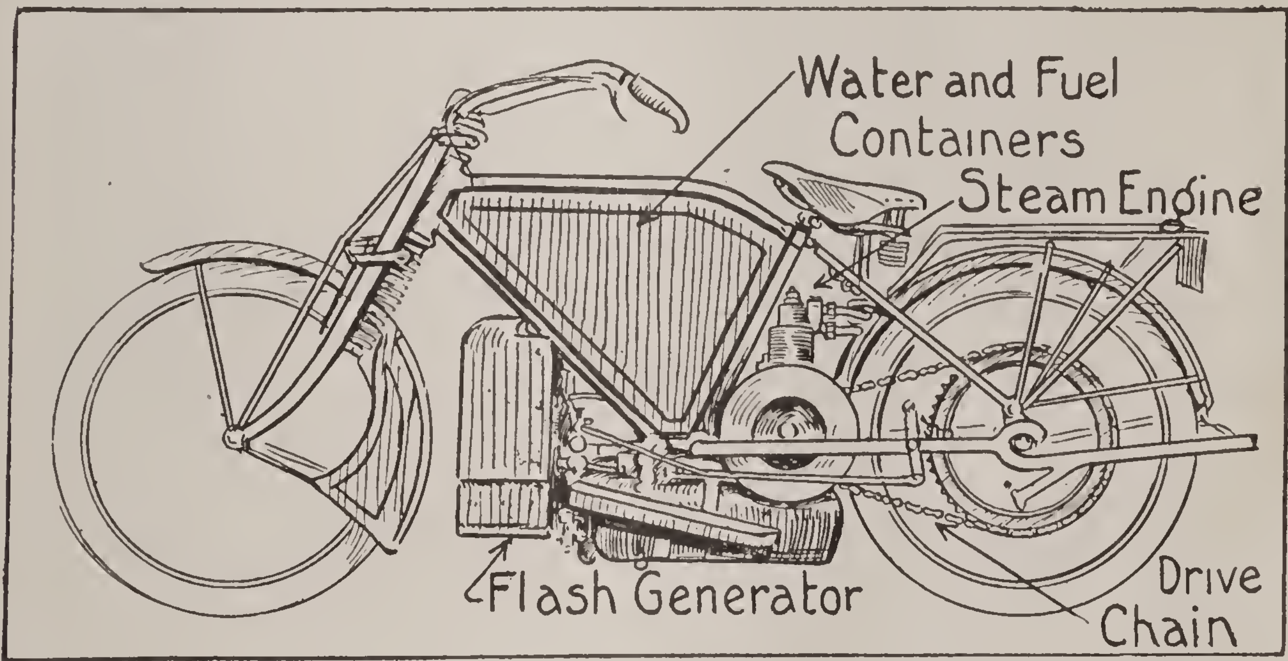

Fig. 14.—The Pearson and Cox Motorcycle. An Unconventional English Design Using Steam as Motive Power.

The heat to flash the water into steam is produced by a burner that utilizes crude oil, the cheapest form of oil fuel. Even though about twice as much of the cheap fuel is needed, as the amount of gasoline consumed by a gas motor of similar capacity, it is claimed that the fuel cost per mile is less than on the internal combustion engine propelled forms. The operation of starting the generator is not unlike that of starting the familiar gasoline torch. A certain amount of the oil is allowed to drip into a suitable shallow pan, and this puddle is ignited and heats the oil contained in the vaporizing

coil that forms part of the burner to a high enough point to generate gas, at which time the main fire may be lighted

After the burner fire has been started, a small amount of water is injected into the hot flash coil by an auxiliary hand water pump, and the requisite steam pressure is obtained for starting the engine. Of course, after the vehicle is once set in motion the generation of steam is automatic. The speed and power of the engine may be controlled by a simple throttle valve in the steam line between the generator and engine cylinder which may be operated very easily from one of the grips. While this machine has had some sale in England, it is doubtful if the ease of control and smooth operation permitted by steam power offers enough advantages over the gasoline motor to make steam power a factor in motorcycle design. There is an added disadvantage in connection with steam power that the average rider will not take kindly to, and that is the possibility of a disastrous fire occurring, should the fuel tank spring aleak and allow the liquid fuel or fumes due to its evaporation to come in contact with the naked flame at the generator.

The use of the gasoline motor as a source of power for motorcycles is, therefore, general and it can be stated with truth that the internal combustion engine is really the only practical form of power plant for motorcycle use. The modern forms of gasoline engine are not only simple in construction, easy to understand, reliable and economical, but are also flexible enough and have sufficient reserve power so that there really would be no advantages of moment obtained by using steam or electricity that would outweigh the complication, weight and lack of efficiency that are common attributes of either of these indirect systems of power generation. In a gasoline engine, the fuel gas is converted into power directly in the engine cylinders, whereas with a steam engine it is necessary to convert water into steam and direct the steam to the engine cylinder to produce the power. Obviously the efficiency or amount of useful power obtained by burning a given quantity of fuel would be greater if it was utilized directly in the cylinder or by the internal combustion process than if burned under a steam boiler where a large part of the heat would be wasted in the form of exhaust gas through the boiler flues.

While motorcycles cannot be classified into types by the form of

power used, as is possible with automobiles, they may be grouped into various classes depending upon their weight, the amount of power provided, the type of gasoline engine used, the method of power transmission, or the use to which the machine is adapted.

For example, motorcycles are constructed even at the present day that have engines of lower power, and which are correspondingly light as a result. Such machines are called "light-weights," a typical example of which is shown at Fig. 15. A light-weight motorcycle is not much heavier, as far as the frame is concerned, than the usual form of roadster bicycle, and the power plant need not be over 2.50 horse-

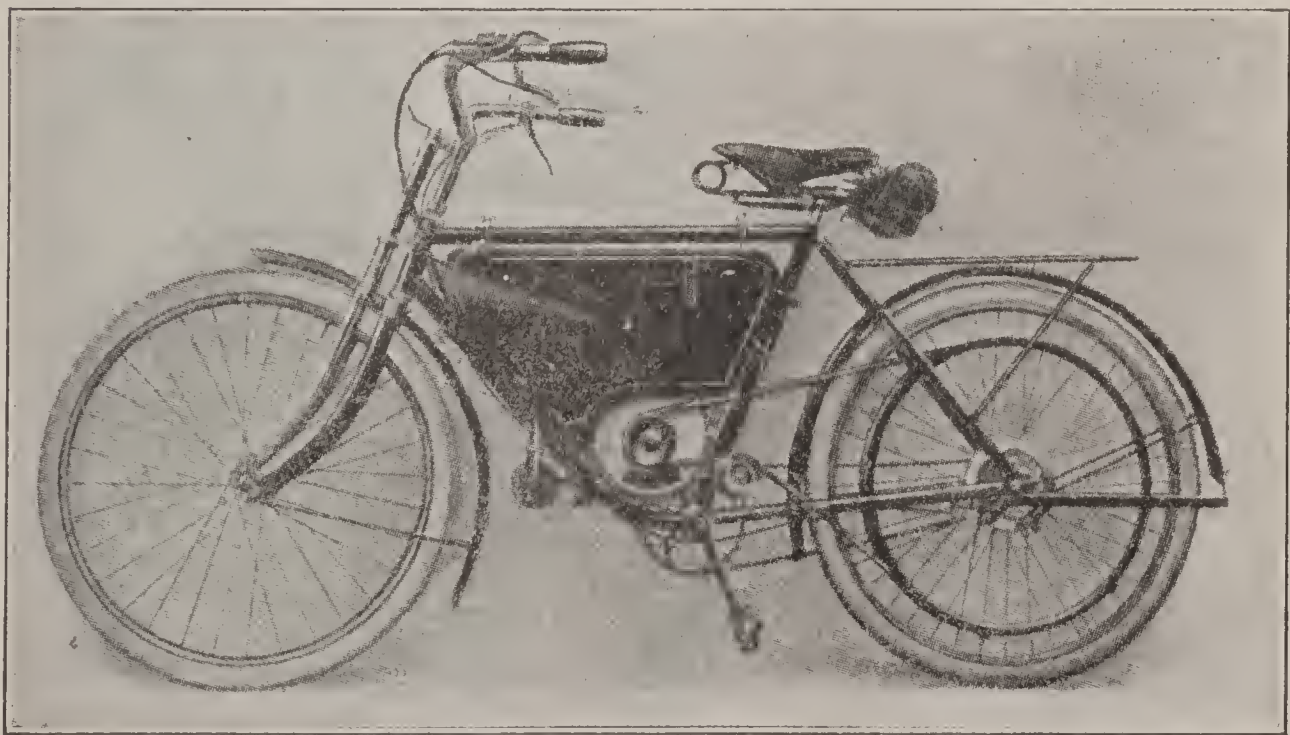

Fig. 15.—The Motosacoche. A Typical European Lightweight Type.

power. A light-weight motorcycle provided with a two-wheeled front axle instead of the conventional single wheel is shown at Fig. 16. A tricycle of this type is intended for elderly persons, women, or young people who do not desire to travel at high speeds, yet who wish to experience the pleasures of motorcycling, with maximum safety. Light-weights may be of two forms, according to the type of power plant used. They may be either single or double cylinder and the gasoline engine employed may operate on either the two-cycle or four-cycle principle. The next class of machine is the medium-weight, while the third classification is composed of the powerful touring

motorcycles which are usually termed "heavy-weights," on account of the strong construction and large power plants used.

Either the medium-weight or heavy-weight machine may be divided into three general groups depending upon whether the machine is used for pleasure, business or racing. The medium-weight machines may be "singles," on account of using one-cylinder engines, or "twins"

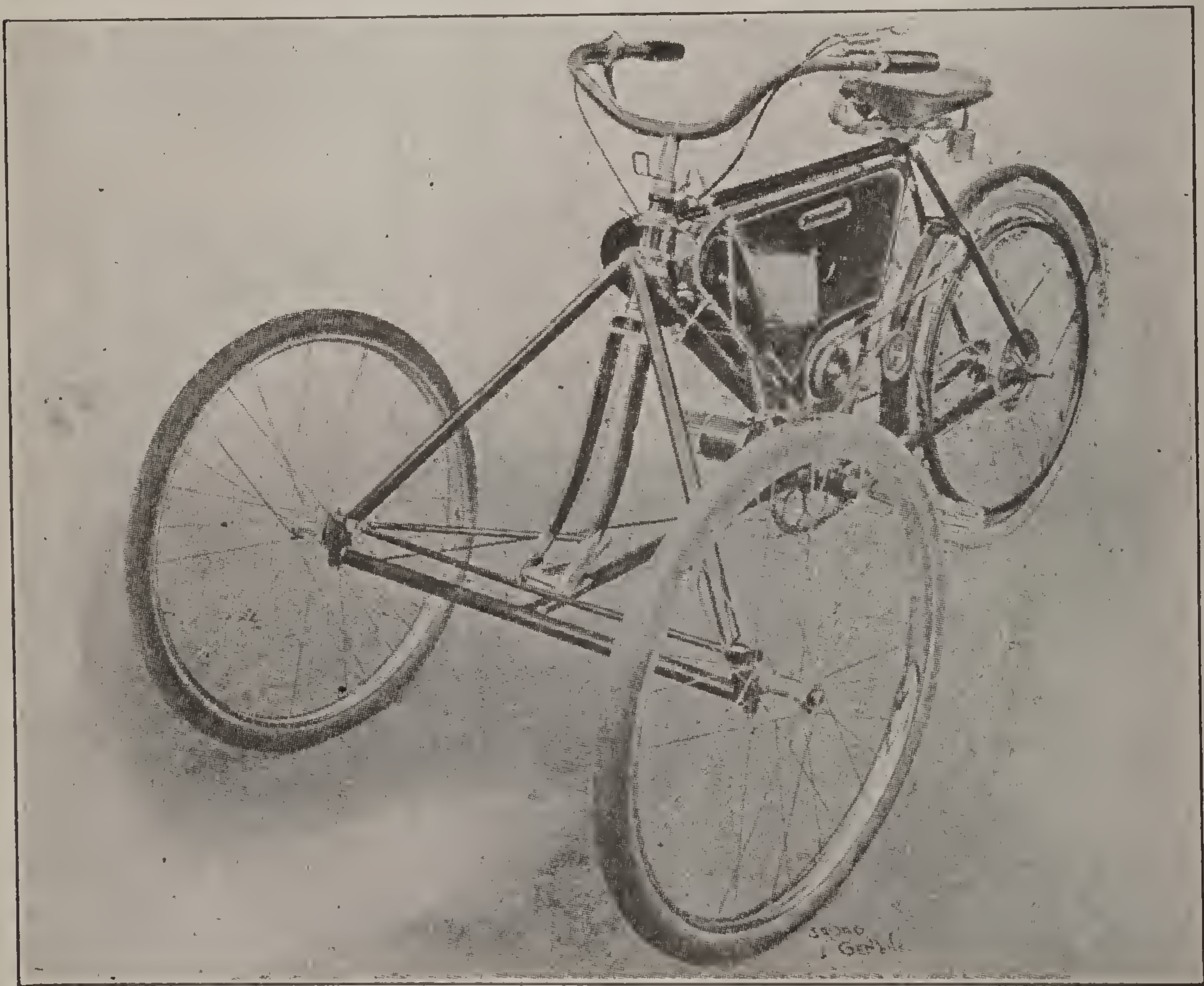

Fig. 16.—Lightweight European Tricycle With Motosacoche Power Plant.

because two-cylinder power plants are utilized. A single may be either belt or chain drive, or the engine may be two-cycle or four-cycle. A heavy-weight machine may employ any one of three types of power plant, as some are provided with large single-cylinder motors while others utilize powerful two or four-cylinder power plants. Then again, all machines may be grouped into two general classes, "single geared," if only a free engine clutch is provided, and "two speed" or

"variable speed," if some form of change speed mechanism, as well as a clutch is included in the design. It is, therefore, extremely difficult for one to classify motorcycles intelligently, though for the purpose of description they may be grouped into, the light, medium, or heavy-weight types without considering the form of power plant used, the method of drive or any of the individual characteristics of the various designs.

Light=weight vs. Medium=weight Construction.—Of the three classes, machines that might be included in the true heavy-weight class are so rare that there are really only two distinct types to be considered. Fully 90 per cent. of the motorcycles in general use may be grouped in either the light-weight or medium-weight classification. The light-weights are obtainable in various forms as we find in the domestic and foreign market machines that range in capacity from 1.75 to 2.75 horse-power, some of which use single cylinder motors while others employ small two cylinder engines. The light-weights usually range between 80 pounds and 140 pounds. Practically all light-weight machines, even if they utilize variable speed gearing, retain the pedalling gear. Where the roads are good, the light-weight has much in its favor. In initial cost, it is comparatively inexpensive and is economical of maintenance on account of the large mileage possible on small quantities of fuel and lubricating oil. A light-weight machine is easy to ride, start and control in traffic. A light-weight machine may be carried up or down a short flight of steps into a house without much trouble, and in the event of a serious breakdown the lighter forms may be propelled by foot power without undue exertion if the transmission system is thrown out of action. The light-weight machine, however, has the disadvantages incidental to the use of low-powered engines. These are lack of speed, hill climbing ability and lack of capacity for rough road work. The light-weight type appeals to people of conservative taste, or to the middle-aged and it is also a very suitable form of machine for those who are active and not very far advanced in age to start on. It is claimed by many authorities that motorcycle manufacturers have reached the extreme in catering to the riders demanding speed and power, and it is certainly true that the most powerful machines are difficult to handle, and are more expensive to maintain than the simpler and lighter forms.

The most important class of motorcycle is the medium-weight machine which, for the most part, is provided with engines ranging from 3.50 to 6 horse-power. While these machines are generally intended for carrying a single passenger and are not well adapted for the attachment of side cars or delivery vans, still they have sufficient power to carry a tandem attachment on fair roads, that are not too hilly. Of course, if fitted with a free engine clutch and two-speed gear, medium-weight machines may be used in connection with side car or delivery van work, if the gear ratio is intelligently selected. If not more than 4 or 5 horse-power is desired, a single-cylinder engine

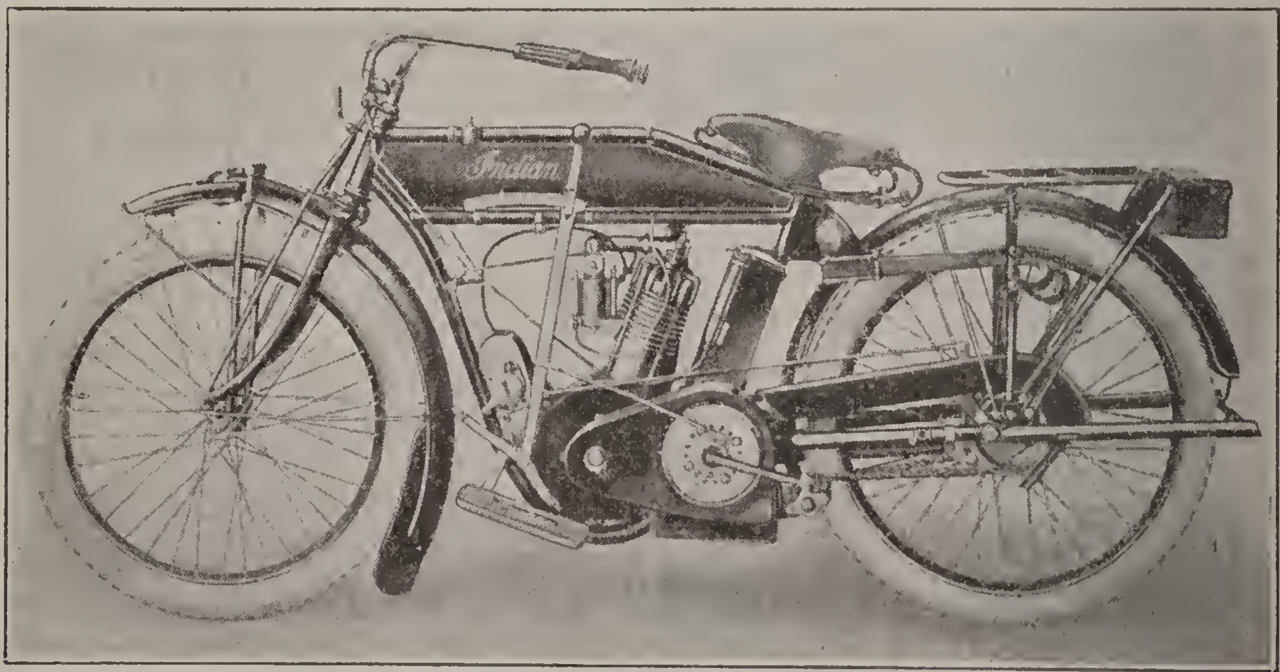

Fig. 17.—Standard 1914 Model Single Cylinder Indian Motorcycle.

will prove very satisfactory, and while the greater part of the demand, at the present time, seems to be for powerful twins, it is evident to one who analyzes the situation carefully that there will eventually be a reaction in favor of the one-cylinder type on account of its economy, simplicity, and ease of operation. To be thoroughly practical and capable of surmounting difficulties ordinarily met with, the machine of the future must include a variable speed gear as well as free engine clutch. The single-cylinder motorcycle shown at Fig. 17 is a representative American type that is a good example of the single-cylinder medium-weight class. At Fig. 18 a medium-weight single-cylinder machine of English design with its important parts outlined is clearly

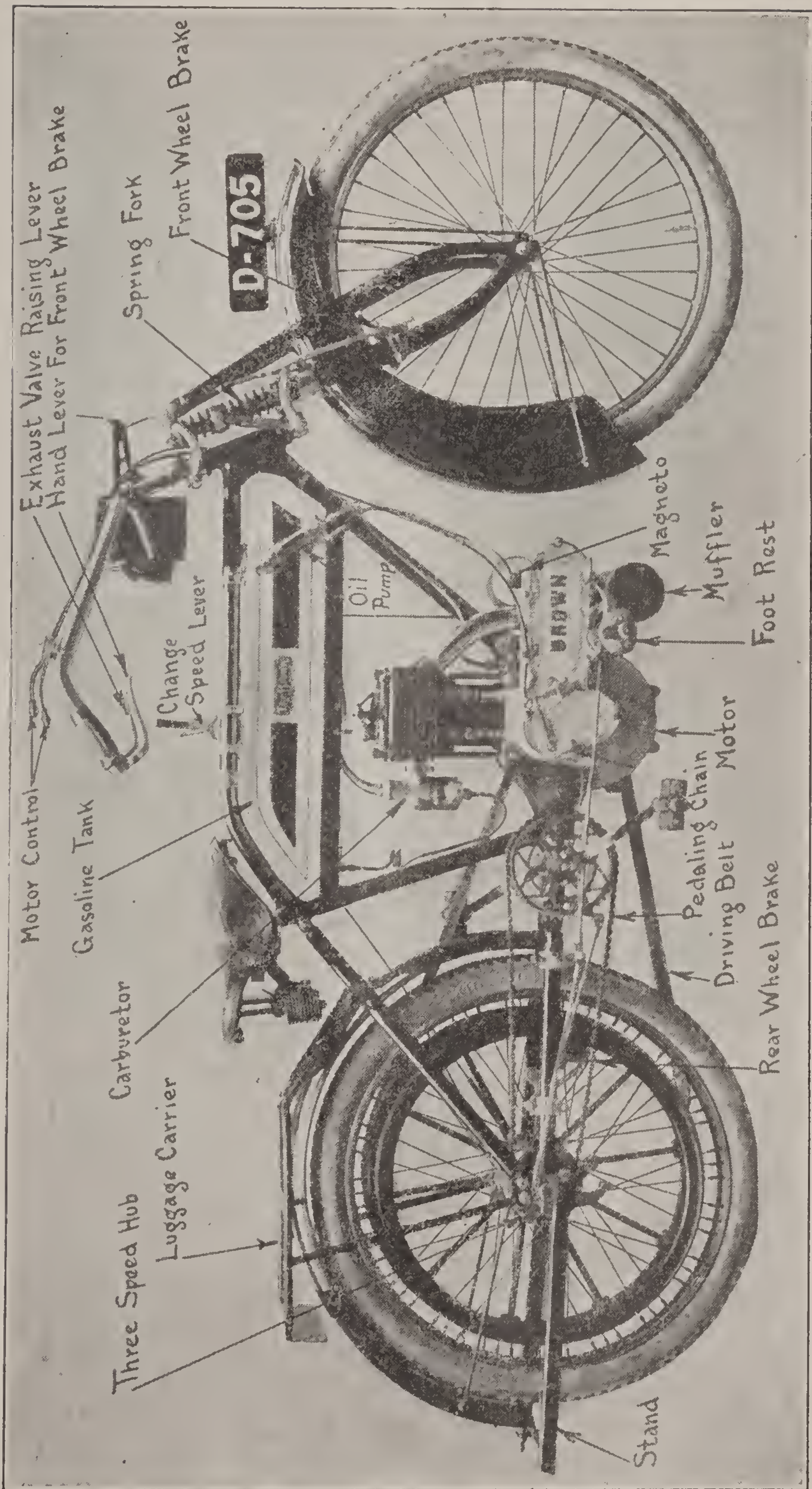

Fig. 18.—The Brown (English) Motorcycle With Important Parts Clearly Indicated.

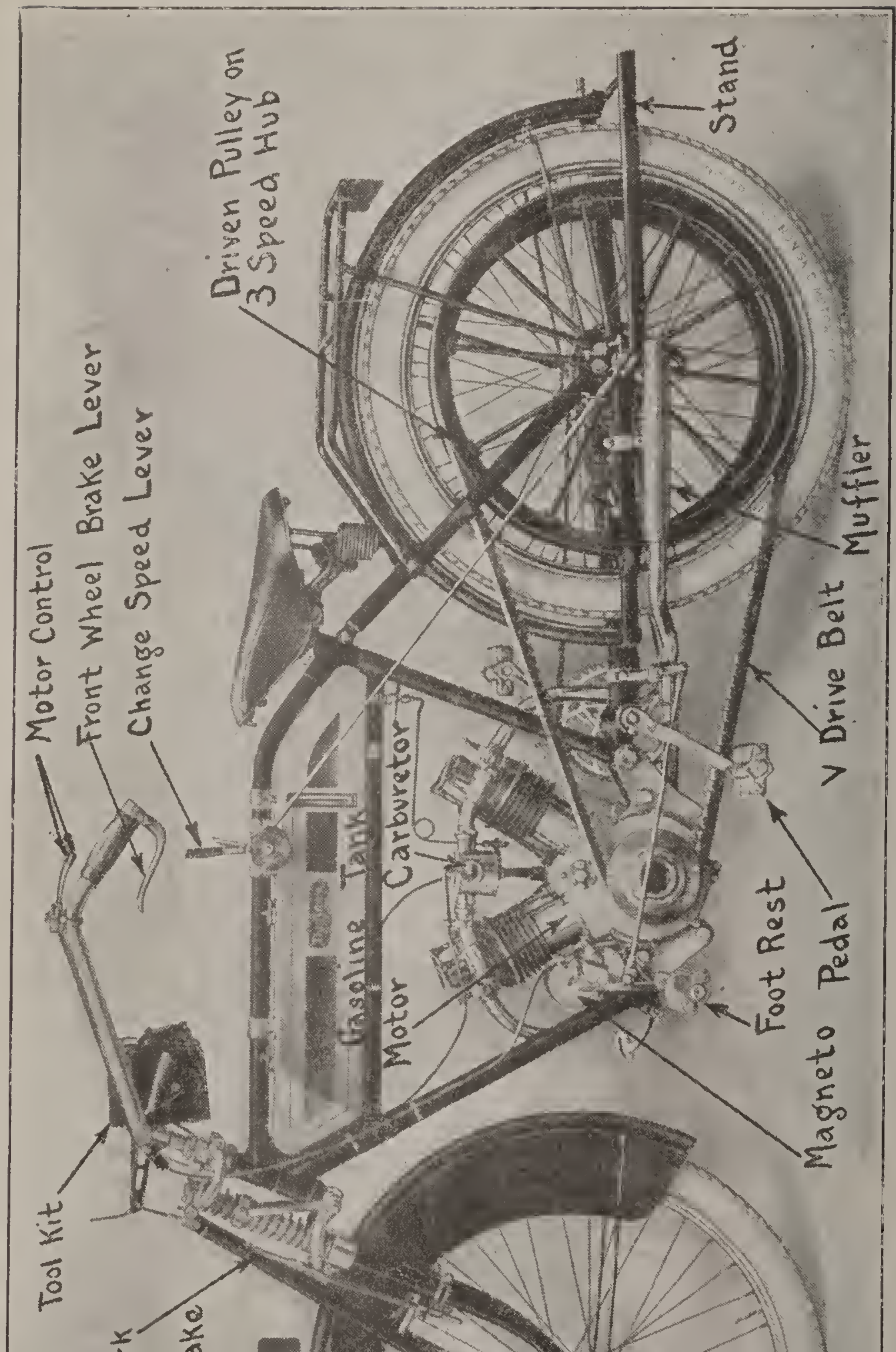

Fig. 19.—The Brown Light Twin Motorcycle.

depicted. An example of the medium-weight machine with small twin-cylinder engine and three-speed variable gear in the rear hub is shown at Fig. 19. It will be observed that the American machine is of the chain drive type, whereas the English designs employ V-belts for power transmission. The medium-weight machine answers practically all of the requirements of the average rider, as it is sufficiently fast and powerful to make it a good touring machine and its construction is heavy enough to enable it to withstand the stresses incidental to operation on rough roads. At the other hand, the medium-weight machine can be handled by any person of average strength, and very satisfactory mileage is obtained from lubricating oil, gasoline and tires.

In the heavy-weight classification, we have the powerful twins and four-cylinder machines rated at from 7 to 10 horse-power, which have ample capacity to handle a side car or delivery van, and which, for the most part, are provided with variable speed gears, and seldom with single-cylinder engines. It is hard to define sharply the distinguishing line between the medium and heavy-weight classes, though most medium-weight machines weigh less than 210 pounds, while the heavy-weight machines will vary between that minimum and a maximum of about 300 pounds with full equipment. A typical machine that may be considered as being on the border line between the heavy-weight and medium-weight classes is shown at Fig. 20. This is an American design and is fitted with a motor rated at from 7 to 9 horse-power, and a variable speed gear. A machine of the true heavy-weight class which is equipped with a four-cylinder power plant is shown at Fig. 21.

On this machine it will be noticed that the usual form of pedaling gear is omitted entirely, because the machine is so heavy that it would be practically impossible to pedal it for any distance in event of breakdown of the power plant. Fortunately, the gasoline engine has been developed to a point where serious derangements are practically unknown, and on most of the medium-weight machines the usual pedaling gear is provided only to facilitate starting and to provide for brake operation rather than as a means of propulsion. A machine of the type shown at Fig. 21 is practically a two-wheeled automobile and demonstrates clearly how radically different the modern motor-

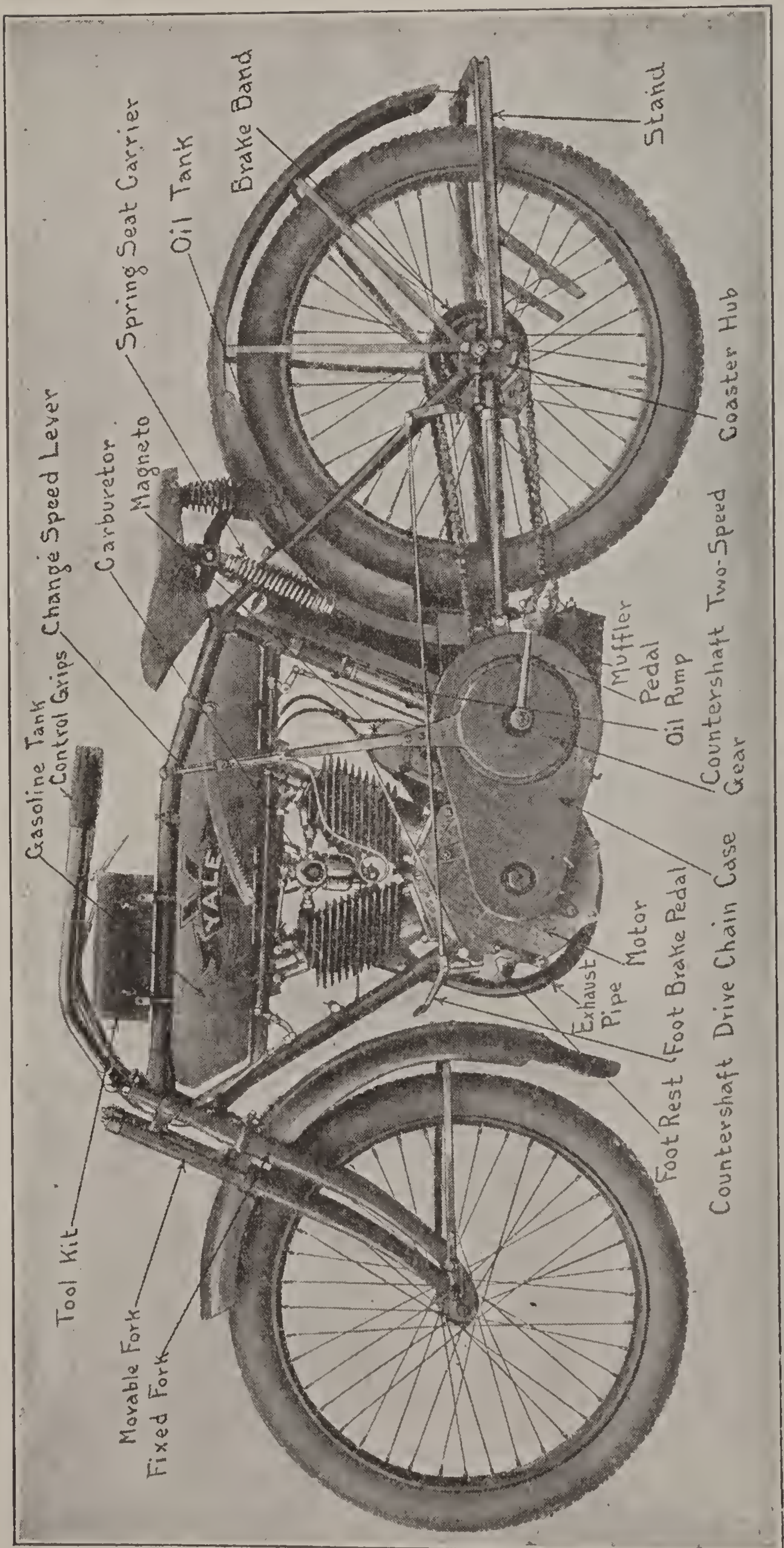

Fig. 20.—The Yale Two Speed Twin Cylinder Model for 1914.

cycle is in construction when compared to the bicycle that formed the basis for the first design.

In the various classes enumerated, one will find machines that have been designed for certain specific purposes, for example, at Fig. 22 is shown a stock racer which is a type of machine that is stripped down to as light weight as possible, and which is geared high in order to obtain the maximum possible speed. The dropped handle-bar makes it easy for the rider to assume a crouching position, which, as we shall see later, makes for minimum air resistance, whereas the elimination of unnecessary weight also makes possible the attaining of high speeds with the same amount of power as would be utilized

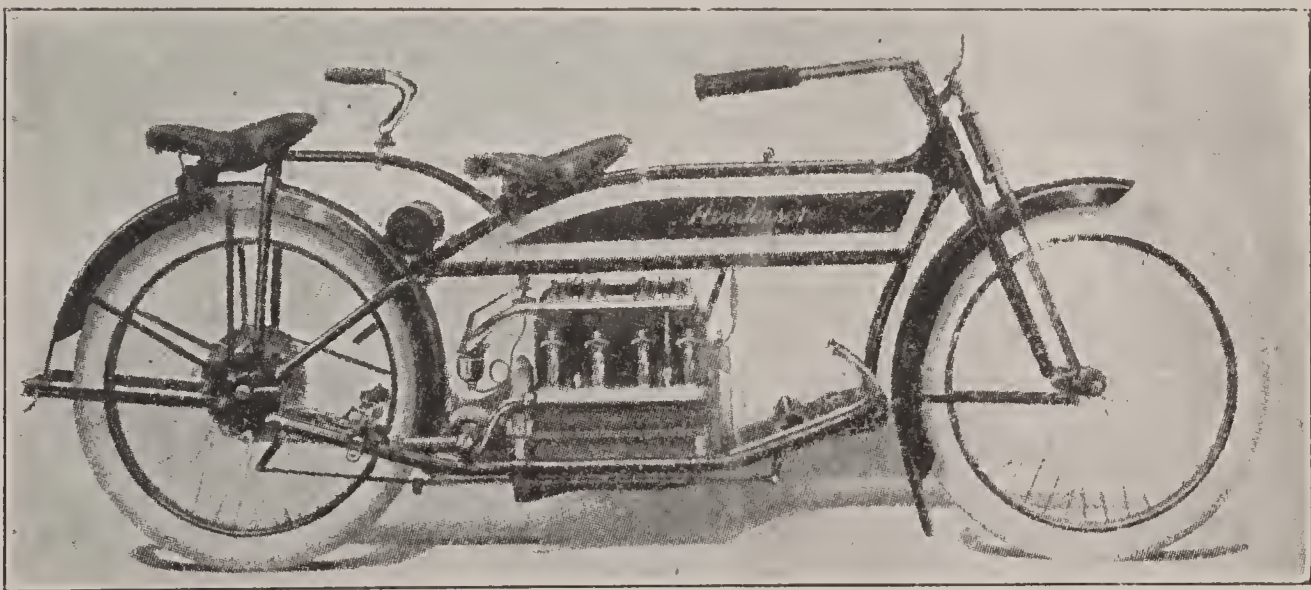

Fig. 21.—The Henderson Four Cylinder Motorcycle With Tandem Attachment.

in a touring machine. Obviously a machine of this type would not be as comfortable for road use as the regular model, on account of the elimination of the spring fork, the upturned handle-bar, the mud guards, foot rests, and other auxiliaries which increase the comfort of the rider. A special form of machine which, while of unconventional appearance, is nevertheless practical, is depicted at Fig. 23. This is intended for the use of women, as it not only has the usual form of open frame, but also carries the power plant far enough forward and has it well protected so as not to interfere with the skirts of the rider. The tri-car shown at Fig. 24 shows the application of the

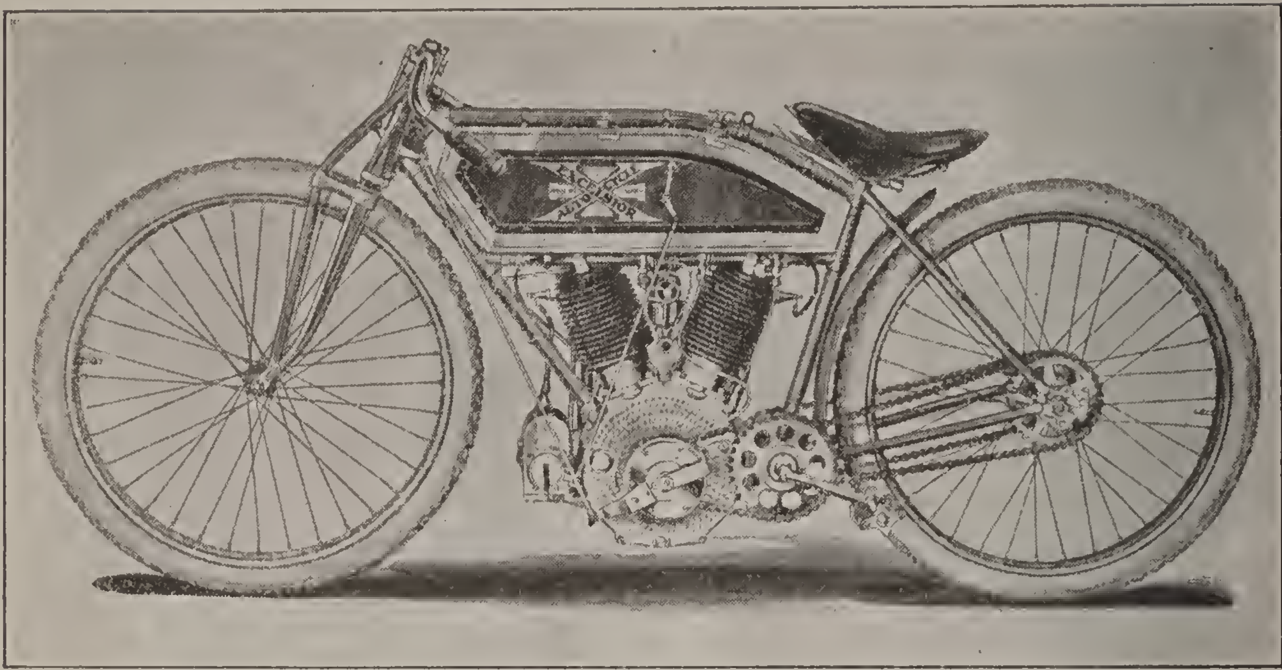

Fig. 22.—The Excelsior Standard Stock Racer.

motorcycle to commercial work, and the vehicle outlined is really a composite form, composed of a two-wheel fore-carriage attached to a twin-cylinder motorcycle. This motorcycle truck weighs complete but 530 pounds and will carry 600 pounds in addition to the weight of the driver. The application of side cars will be considered in a

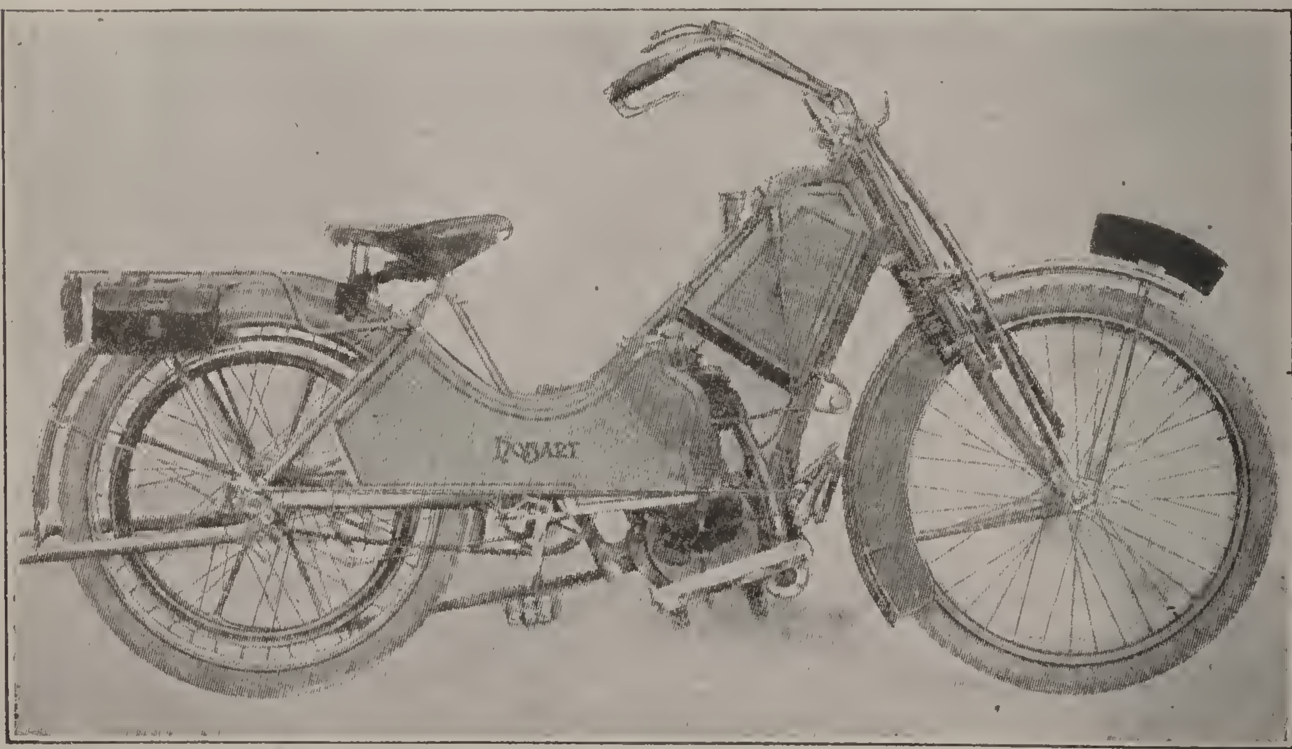

Fig. 23.—An English Open Frame Motorcycle Intended For Women's Use.

chapter devoted to that form of construction. Summing up, it is apparent that no one class of motorcycle will suit everybody. A machine that might be eminently satisfactory to one individual might fail entirely in fulfilling the requirements of another. The low-powered motorcycle is suitable for those who do not care to travel fast or far and who wish an economical machine that is easily handled. The machine of medium weight and moderate power will suit the average individual who wishes a strong machine capable of keeping up a good average on a long trip, and that will have power enough to

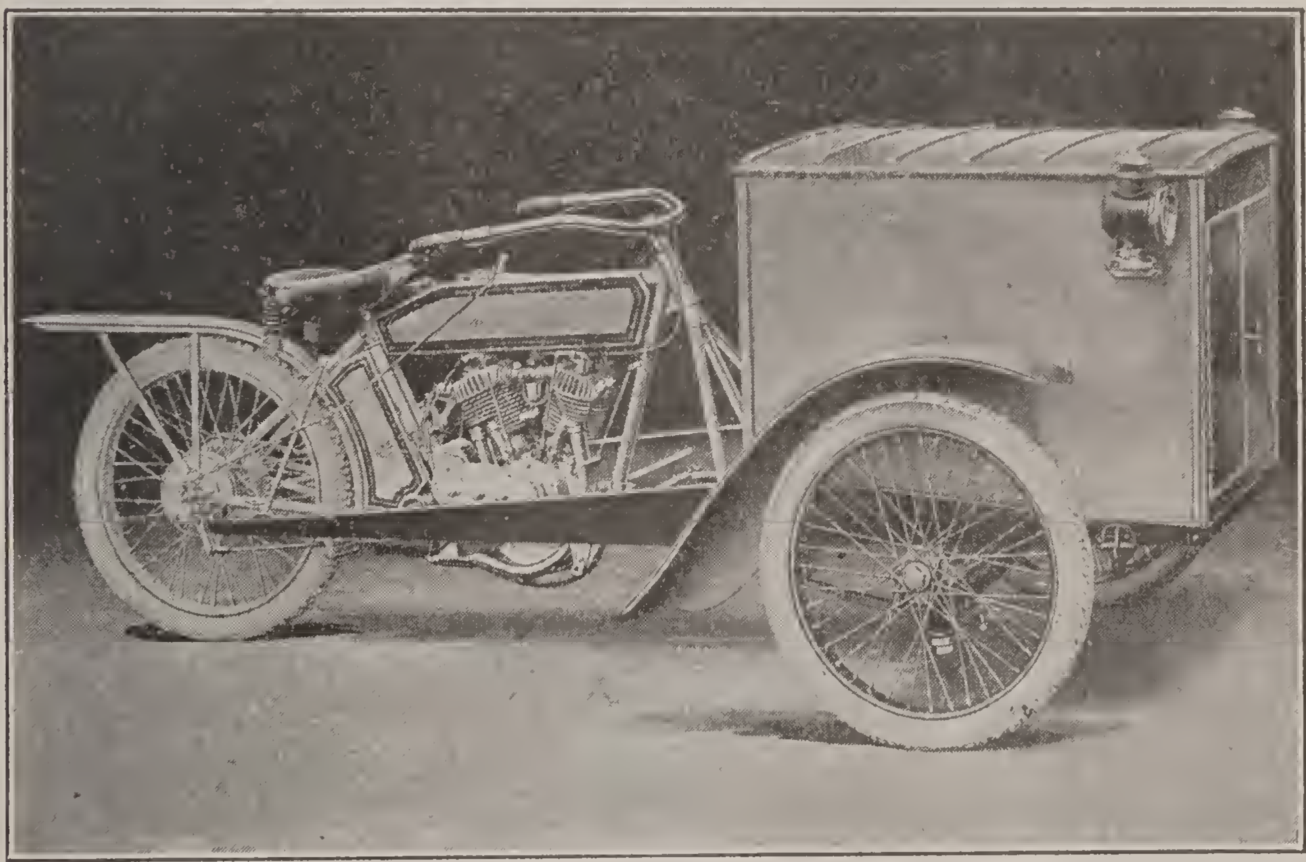

Fig. 24.—The Harley-Davidson Motorcycle Truck, a Commercial Application That Has Proven Thoroughly Practical.

climb average hills and negotiate our ordinary roads. The heavy powerful machine is the mount for the enthusiast or expert who has graduated from the light-weight or medium-weight class, and who does not object to weight or expense as long as his machine is capable of high speeds with a sufficient margin of power to surmount the steepest hills or negotiate the most unfavorable roads.

Determining Power Needed.—The amount of power needed to propel a motorcycle depends upon a number of factors, all of

which are variable. The chief resistance to motion of self-propelling vehicles, such as automobiles and motorcycles, when operated on a level road at low and moderate speeds consists of the rolling resistance at the point of contact between traction member and the ground and friction in driving, power-transmitting and supporting elements. At high speeds one must take into account the factor of air resistance, though at low speeds this can be neglected because of its low value. When a motorcycle is to be propelled up a gradient, one must take into consideration the added resistance due to gravity, and the amount of power required to drive the machine depends upon the weight of machine and rider, steepness of the hill and the speed it is desired to maintain. Obviously, when descending hills, less power is needed than when running up hill or on the level. It takes more power to drive a heavy machine than a light one, other conditions being equal. A smooth-running construction is easier to push than one in which considerable friction exists, and much more power is needed on machines intended for high-speed work than on types where the operating speeds are moderate. No matter how powerful the power plant is, the only available means of determining the capacity of the vehicle is a consideration of the amount of push available at the contact point of traction member and road, so while it is imperative to supply enough power, it is equally important to so distribute the weight as to insure adequate adhesion between traction member and road surface and to have as efficient delivery of power from motor to rear wheel as possible.

Influence of Road Surface on Traction.—The resistance offered by various roads depends primarily on the character of the surface, but it is also controlled to a limited extent by the size of wheels, character of tires and speed. The traction coefficients as given by Norris follow:

On rails or plates..............	5.16	pounds per ton
Asphalt or hardwood..........	12.24	pounds per ton
Macadam......................	30.60	pounds per ton
Loose gravel...................	140 to 200	pounds per ton
Sand..........................	400	pounds per ton

The influence of tires provided may be summed up concisely by

saying that the resistance of iron and solid rubber tires is approximately the same, while with well-inflated pneumatic tires, it will be 25 to 30 per cent. less. The figures given above are for pneumatic tires, though the amount of air pressure in the tires influences the traction resistance to a degree. Hard tires have much less resistance than softer ones. A generally accepted value for well-inflated pneumatic tires is 50 pounds per ton on hard, level asphalt, and this is the basis commonly used in automobile engineering practice. A value of 80 pounds per ton for macadam and hard dirt roads will provide a desirable margin, and can be followed to advantage because motorcycle wheels are relatively small, commonly ranging from 26 to 30 inches in diameter, with 28-inch wheels predominating. Larger diameter wheels, such as used on automobiles, are more capable of rolling over minute obstructions and bridge small hollows easily and with less effort than would be required of supporting members of less diameter. The traction resistance would, therefore, be higher with low wheels than high ones, if the road surfaces were not absolutely smooth. The total effort required to overcome traction resistance R may be approximated by considering the following formula, in which W is total weight of motorcycle and load:

$$\frac{W \times 80}{2{,}000} = R \text{ or } \frac{W \times 4}{100} = R.$$

How Speed Affects Power Needed.—The value obtained by formula is but one of the factors to be considered in determining the horse-power required, therefore it is important to consider velocity of cycle as well. This value is generally taken in feet per minute, so if V is the speed in miles per hour, then

$$\frac{V \times 5{,}280}{60} = 88\ V$$

is the speed in feet per minute, and the horse-power required to overcome traction resistance of a certain vehicle and passengers at a known speed may be derived by the following:

$$\text{H.P.} = \frac{W \times 4}{100} \times 88\ V \times 1/33{,}000.$$

Consider, for example, that it is desired to approximate the power necessary to overcome traction resistance of a motorcycle and passengers weighing 500 pounds at a speed of 40 miles per hour, and that air resistance is neglected for the moment. Substituting known values in the above formula, we have

$$\text{H.P.} = \frac{500 \times 4}{100} \times 88 \times 40 \times \frac{1}{33{,}000} \text{ or}$$

$$\text{H.P.} = \frac{20 \times 3{,}520}{33{,}000} = \frac{70{,}400}{33{,}000} = 2.10 \text{ H.P.}$$

This would indicate that the torque corresponding to 2 horse-power applied at point of contact of traction wheel and ground would be capable of driving 500 pounds at the rate of 40 miles per hour over smooth macadam or dirt road. Let us consider a condition where the road surface would offer a greater resistance to traction and yet permit of the same speed as previously considered, or 40 miles per hour. If the road surface is loose gravel, the resistance will be 200 pounds per ton, and the formula for traction resistance would be:

$$\frac{W \times 200}{2{,}000} = R \text{ or } \frac{W}{10} = R.$$

The complete formula, taking speed into consideration, is:

$$\text{H.P.} = \frac{W}{10} \times 88 \times 40 \times \frac{1}{33{,}000} \text{ or}$$

$$\text{H.P.} = \frac{500 \times 88 \times 40}{10 \times 33{,}000} \text{ or } \frac{1{,}760{,}000}{330{,}000} = 5.33 \text{ H.P.}$$

As the motorcyclist would be apt to meet loose gravel or dirt, the amount of power needed must be figured using the unfavorable roads as a basis. It is not likely that the rider could negotiate a soft road safely at 40 miles per hour, so the amount of power obtained above is somewhat higher than actually needed, because the speed would be reduced as the traction resistance increased. It would be possible to run at 20 miles per hour, however, so figuring power needed on this basis, we have:

$$\text{H.P.} = \frac{W}{10} \times 88 \times 20\, 1/33{,}000 = \frac{500 \times 20 \times 88}{10 \times 33{,}000} = 2.69 \text{ H.P.}$$

It will be seen that the reduction in vehicle speed has made it possible to drive the motorcycle over a gravel road at 20 miles per hour, with but little more power than that needed to drive it over a macadam road at 40 miles per hour. The factor of air resistance must be taken into consideration at a speed of 40 miles per hour, however, so the power needed to overcome air resistance must be added to that required for traction.

Effect of Air Resistance.—A commonly used formula for approximating power needed to overcome the air resistance at various speeds as given by Brooks in which V is velocity of vehicle in feet per second, and A the projected area of front of cycle and rider, is

$$\text{H.P.} = \frac{V^3 \times A}{240{,}000}.$$

This formula assumes still air, so if the cycle is to be driven against a wind of known velocity, this should be added to the cycle velocity. We will assume for simplicity that the motorcycle is to attain a speed of 40 miles per hour in still air. This is equal to a speed of 58.6 feet per second. The projected area will vary with the size and position of the rider, and even with a large rider sitting upright on the average motorcycle, it is not apt to exceed 5 square feet, whereas, if the rider crouches along the tank or rides low, the projected area of machine and rider will not exceed 4 square feet.

This was determined experimentally by photographing a standard machine and medium-weight rider as shown at Fig. 25, having the rider assume two positions. At A he is sitting in the usual road-riding posture or upright, and it is reasonable to assume that this is the position that offers the maximum exposed area against which air resistance becomes effective. The view at B shows the position assumed by most riders on the track, in which the operator's body rests on the tank, and this may be taken as the position that offers a minimum exposed area to air resistance.

As the basis for figuring is the projected area, rather than actual exposed area, it was possible to draw outlines corresponding to the two positions on squared plotting paper as at Fig. 26. The photographs were of such a size that each square represents one square inch in area. Therefore, by counting the squares, it was not difficult to

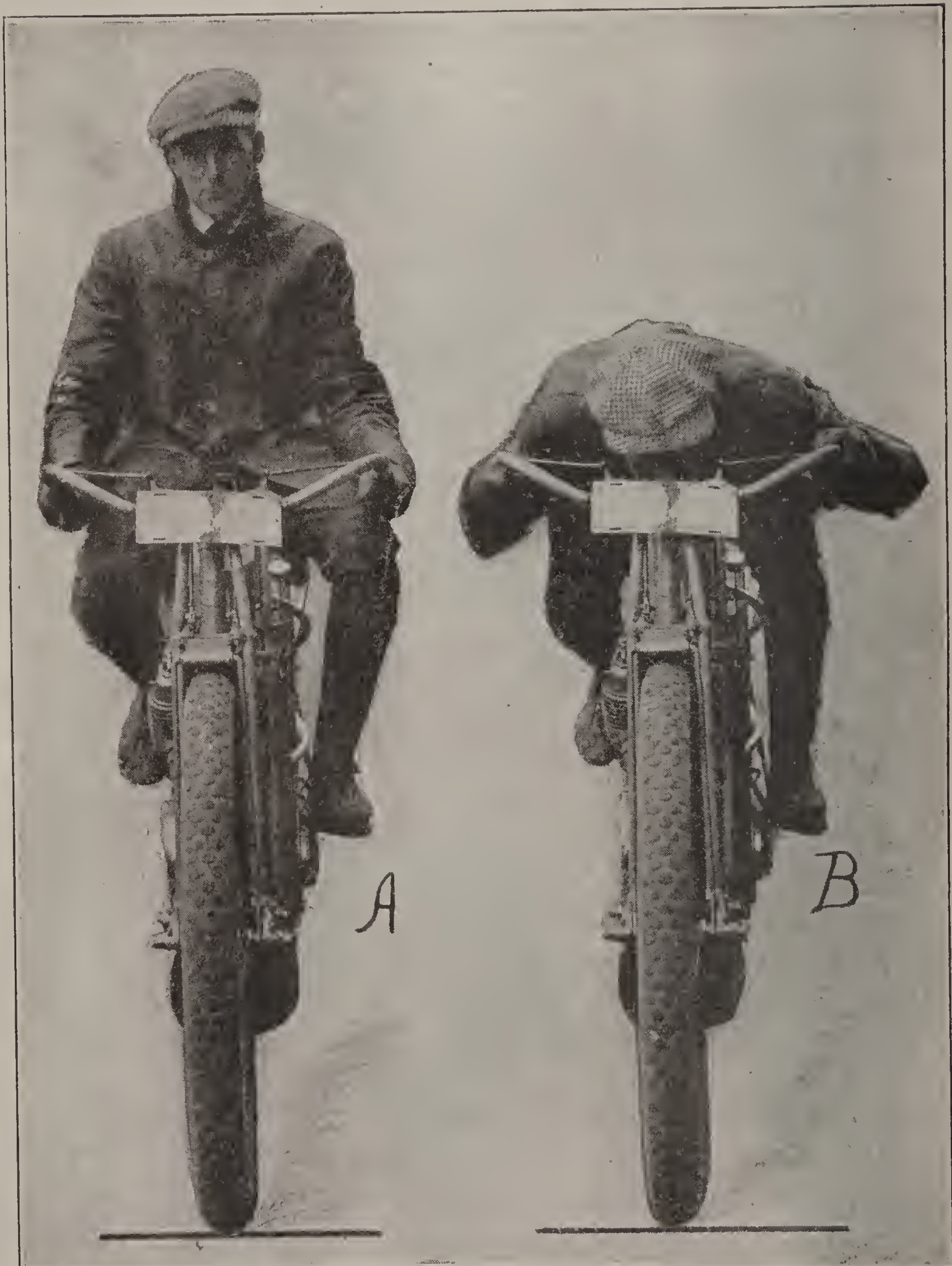

Fig. 25.—Showing Position of Rider For Road Work at A and When Minimum Air Resistance is Desired at B.

approximate the area of the rider and machine in the two positions. As a check upon this simple method, the areas were computed with a planimeter and were found to agree very closely with the areas obtained by counting the squares.

Using the Brooks formula and substituting known values, we have:

$$\text{H.P.} = \frac{58.6^3 \times 5}{240{,}000} = \frac{201{,}050 \times 5}{240{,}000} = 4.14 \text{ H.P.}$$

To overcome the resistance of air at speeds of 60 miles per hour, or 88 feet per second, with rider in crouching position, we have the following:

$$\text{H.P.} = \frac{88^3 \times 4}{240{,}000} = \frac{681{,}472 \times 4}{240{,}000} = 11.3 \text{ H.P.}$$

From the example previously considered, this means that it will require 2.1 horse-power to overcome traction resistance of a 500-pound motorcycle and load at 40 miles per hour, and 4.14 horse-power to overcome the air resistance, this making a total of 6.24 horse-power to propel a 500-pound motorcycle and load on a level road at a speed of 40 miles per hour. If only level roads were to be considered, or highways having a good surface, a 7 horse-power motorcycle power plant would be ample for all requirements up to a speed of 40 miles per hour, and would carry two passengers easily under these conditions, if there was no loss in power transmission elements. Owing to this loss, the power plant should be capable of delivering that amount of power to the rear wheel after all losses have been deducted.

How Gradients Affect Power Required.—A motorcycle must be capable of surmounting any gradient apt to be met *en tour* if it is to be considered a practical conveyance, so another item that must be reckoned with in determining power required is the ability to climb hills. The amount of power needed depends on all the factors previously considered, such as condition of road surface, the speed it is desired to attain, weight of machine and passengers, and in addition one must take cognizance of the steepness or pitch of the grade.

The ability of a motorcycle to climb hills depends upon correct application of power to the traction member as well as ample power plant capacity. An engine of relatively small power may be suitable

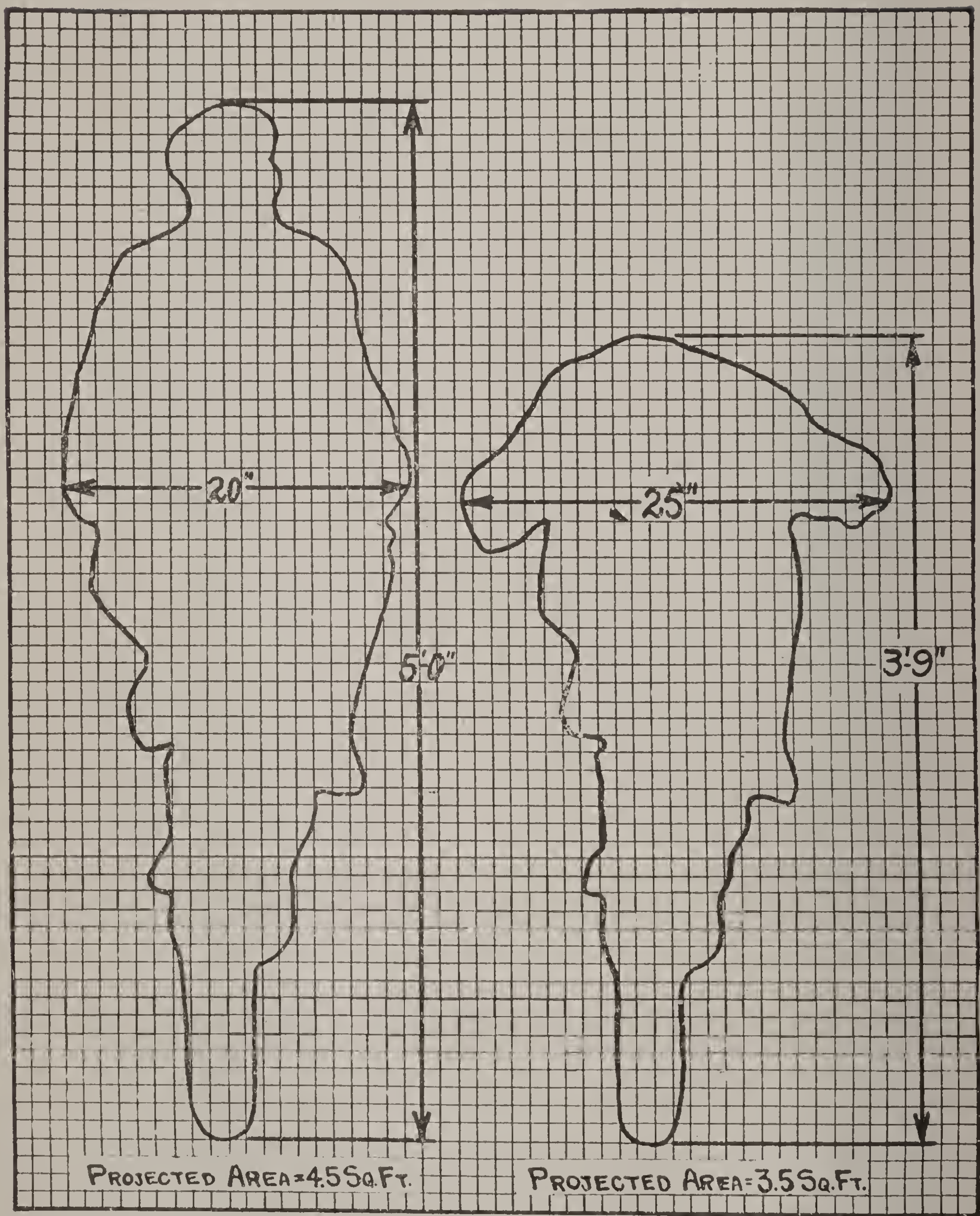

Fig. 26.—Diagram Illustrating Method of Estimating Projected Area of Motorcycle Rider in Two Positions.

to push a motorcycle up a very steep hill if the gear ratio between engine shaft and rear wheel is low enough; at the other hand, an engine of twice the power would not enable one to climb a hill if the gear ratio was too high. With a one-gear machine, it is necessary to

use a gear ratio that is a compromise between the two extremes, in order not to sacrifice speed too much on the level, as when the gear ratio is low; or hill-climbing ability, as when the ratio of drive is high. If a two-speed machine is used, one can have a high gear that will permit of any speed within the capacity of the power plant and yet have a gear suitable for ordinary running conditions without going into the low speed. The lower ratio will permit the rider to negotiate sand or hills at a low speed, and yet the engine can be run fast enough to develop its full power.

It is necessary to exert an effective push between traction member and the ground equal to 1 per cent. of the total load for each 1 per cent. rise or pitch. For example, to climb a hill having a rise of 20 per cent. or one foot rise for every five feet in horizontal distance, it will be necessary to add an effective push at traction member equal to 20 per cent. of the total weight to the power ordinarily required on the level road having the same character of road surface as the hill to be surmounted.

Considerable difference of opinion obtains as to the methods of calculating grade percentages, and some confusion may exist in the mind of a non-technical reader regarding the difference between the percentage and angle of a grade. A diagram is given at Fig. 27, which shows the method in vogue graphically. If it is assumed that the base of the triangle represents a line 1,000 feet long, and that the first sloping line represents a road having a rise that brings it 50 feet above the starting point, this would be considered as a rise of 50 feet in 1,000 feet or 1 to 20, and would correspond to a 5 per cent. grade. The rise is based on the length of the base line, not of the hypotenuse of the triangle, which is represented by the inclined roadway. A grade which represents 100 per cent. corresponds to an angle of but 45 degrees, not perpendicular, as is commonly supposed. When the grade becomes steep enough so the angle of inclination is over 30 degrees, gravity overcomes traction and some positive method of drive, such as gear wheels running on toothed tracks, is necessary to climb greater gradients than 30 degrees angle.

The following table gives the percentages and corresponding angles of inclination for gradients ordinarily met with, except in the very mountainous sections of the country:

TABLE OF GRADIENTS.

Grade.		Equal to Angle of	Rise or Fall in One Mile Feet.
Per Cent.	Units.		
20	1 in 5	11 deg. 19 min.	1,056
17	1 in 6	9 deg. 26 min.	880
14	1 in 7	8 deg. 9 min.	754
12.5	1 in 8	7 deg. 8 min.	635
11	1 in 9	6 deg. 17 min.	586
10	1 in 10	5 deg. 43 min.	528
9	1 in 11	5 deg. 11 min.	480
8	1 in 12	4 deg. 46 min.	440
7.75	1 in 13	4 deg. 24 min.	406
7	1 in 14	4 deg. 5 min.	337
6.5	1 in 15	3 deg. 49 min.	352
6.25	1 in 16	3 deg. 35 min.	330
6	1 in 17	3 deg. 22 min.	310
5.5	1 in 18	3 deg. 11 min.	293
5	1 in 20	2 deg. 52 min.	204

We have seen that a torque or push corresponding to 7 horse-power, at point of contact of traction wheel and ground, would be capable of propelling 500 pounds at the rate of 40 miles per hour over a smooth dirt road not having any rise, air resistance included. At this speed, the 28-inch traction wheel would be making a little less than 500 revolutions per minute. This is equal to a torque that can be easily obtained by the following simple formula:

$$\text{Torque or T} = \frac{\text{H.P.} \times 63{,}024}{\text{R.P.M.}}$$

Substituting known values in above equation, we find that

$$T = \frac{7 \times 63{,}024}{500} = 882.3 \text{ inch-pounds at center of wheel.}$$

To find torque at point of contact between rear wheel and ground, the

turning moment at center of wheel must be divided by wheel radius, or 14, giving a value of 63 pounds push. To climb a 20 per cent. grade, one would need an additional effective push of 100 pounds, which is 20 per cent. of the total weight to be moved of 500 pounds. To maintain a speed of 40 miles per hour up a 20 per cent. grade, an engine of very high power would be needed. To illustrate, if the engine was running at 2,500 revolutions per minute, a ratio of 5 to 1 would permit the rear wheel to turn 500 times per minute. From

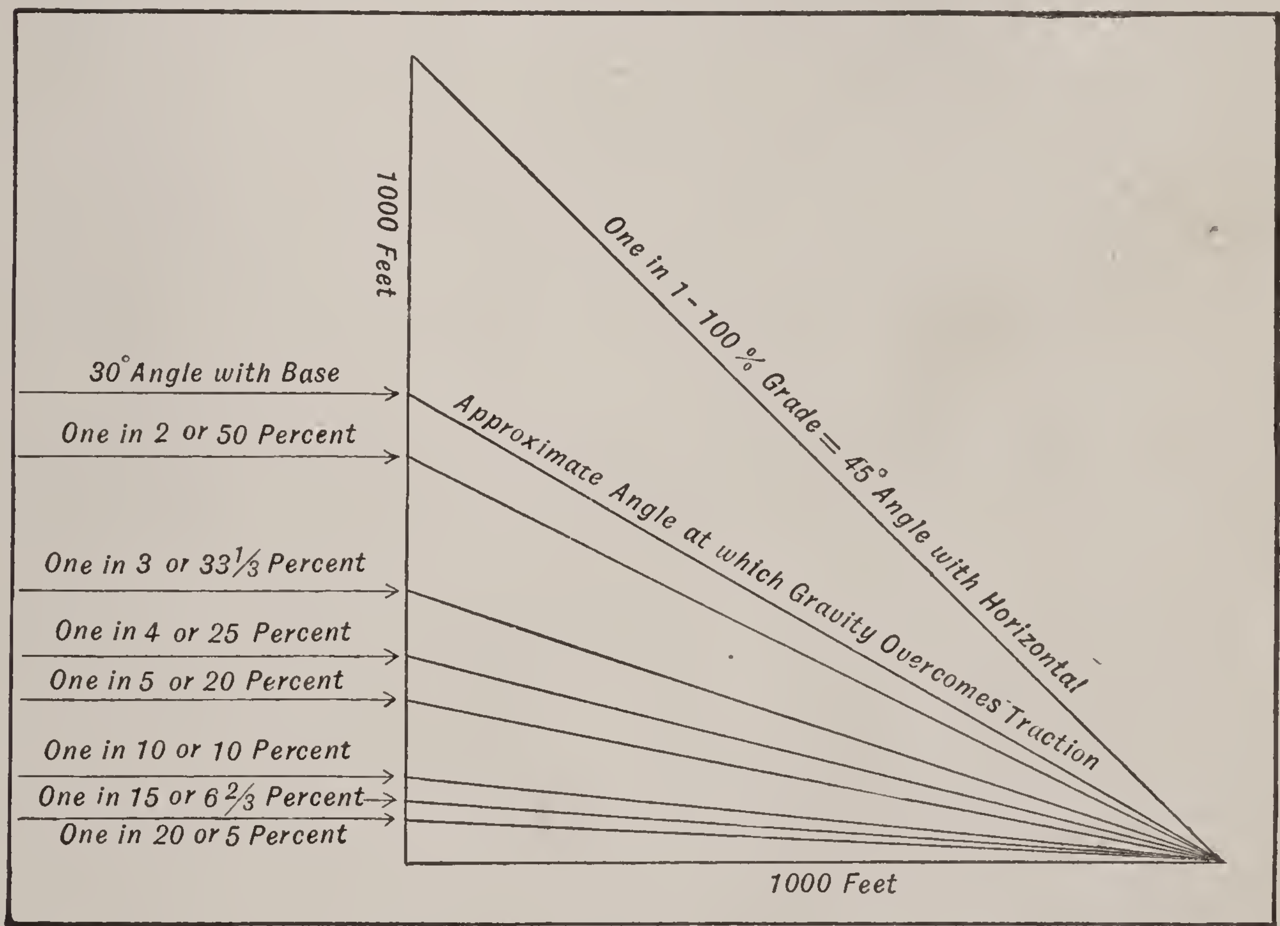

Fig. 27.—Diagram Showing Method of Calculating Grade Percentage.

the data at hand, it will not be difficult to figure the motor horse-power needed. To the push of 63 pounds necessary to overcome traction and air resistance, an additional push of 100 pounds must be added. This will be a total push of 163 pounds at 14 inches radius, which is equivalent to 2,282 inch-pounds at wheel center. This torque could only be obtained by expenditure of 18.1 horse-power. Obviously, it would not be practical to use engines of this capacity, so the speed would have to be reduced when climbing any hill of magni-

tude to correspond to the severity of the ascent, and the gear ratio must be selected carefully in order to enable the engine to run sufficiently fast to develop its maximum horse-power.

If the speed is reduced to 20 miles per hour, as could be easily done by using a slow-speed gearing giving a rear-wheel speed of half that needed to cover 40 miles per hour, without cutting down engine speed, much less power would be needed to move the same weight. At 20 miles per hour, air resistance would be so slight it could almost be neglected, requiring less than 0.5 horse-power to overcome it. The formula for finding power necessary to overcome traction resistance would be:

$$\text{H.P.} = \frac{500 \times 4}{100} \times 88V \times \frac{1}{33{,}000}$$

Substituting known values, we have:

$$\text{H.P.} = \frac{20 \times 88 \times 20}{33{,}000} = \frac{35{,}200}{33{,}000} = 1 \text{ H.P.}$$

This would be equal to a torque of 252 inch-pounds at wheel center or a push of 18 pounds at tire. Add to this 100 pounds to overcome resistance of gradient, and we obtain a torque of 118 pounds at 14 inches radius, or 1,652 inch-pounds at wheel center. This torque could be easily delivered by a 6.5 horse-power motor, neglecting losses in transmission which, however, would be geared down 10 to 1 on account of the interposition of slow speed gearing.

If we had a machine with a gear of 5 to 1, the motor should be capable of delivering 6.5 horse-power to the traction wheel at a speed of 1,250 revolutions, instead of at 2,500 revolutions per minute which would call for a considerably heavier and larger power plant on account of the greater piston displacement necessary to develop the same power at the lower speed.

Power in Proportion to Weight.—The amount of power used by motorcycle designers does not vary materially for similar weights of machine, though the amount of useful energy available for traction depends on many other conditions besides nominal horse-power of motor. The average single-cylinder machine, equipped with a 4 to 5 horse-power engine with full equipment of accessories, will weigh less than 200 pounds; this is 1 horse-power for every 40 to 50

pounds vehicle weight. Several prominent light-weight machines of European build have engines rated at 2½ horse-power and weigh well under 100 pounds. The average twin-cylinder motorcycle, with high gear ratio to permit of speed, must have more engine power in ratio to weight than a machine intended for touring, in order that it may have some hill-climbing ability. The weight of a number of prominent twin machines as determined by the writer varies between 250 to 300 pounds with full equipment. The engine power given by the makers, which is a purely nominal rating figured by the simple empirical formula of the S.A.E., is much under the actual capacity of the engine because this determination is made by using a piston speed constant that is much less than that possible in motorcycle engines. The nominal ratings vary from 7 to 9 horse-power, the power plant of lesser capacity being furnished for the lighter machines. This would make the nominal power ratio to weight about 1 horse-power for each 35 pounds motorcycle weight. The actual ratio is much higher than this, as engines rated at 7 to 9 horse-power have developed twice this in brake tests, so the true ratio of power to weight in twin machines of American design is about 1 horse-power for every 20 pounds.

As will be apparent, the addition of one cylinder to a motorcycle engine will practically double its power without a corresponding increase in weight. The engine is no heavier, save for the added cylinder and its internal mechanism, and the increase in size of frame parts, transmission elements and tires to provide adequate resistance to the stresses imposed by the larger power plant does not increase the weight materially. The average practice seems to be to provide about 1 nominal horse-power for each 50 pounds weight in touring motorcycles with a gear ratio that will not permit of high speeds and 1 nominal horse-power for each 35 pounds weight in fast, twin-cylinder machines. The foreign rating, because of the uniformly better roads in England and France, as well as general use of variable speed gears, is somewhat different, the average being about 1 nominal horse-power for each 50 pounds cycle weight.

Influence of Modern Automobile Practice.—When the motorcycle was first conceived, it was clearly the intention of the inventors to follow bicycle lines in their entirety, and to change the design only

as much as was necessary to apply the internal combustion motor and its auxiliary devices. The first aim was simplicity, as it was believed that most of the recruits to the motorcycle would come from the vast army of wheelmen and that, unless one conformed very closely to the construction with which they were all familiar, they would not take kindly to the power-propelled forms. This same impression was current among early automobile designers, and for the first few years motor-propelled vehicles did not differ much in appearance from the horse-drawn carriages of the period. It did not take automobile designers long to realize that the requirements of the two forms of conveyances were radically different, and the true development of the automobile dates back to the time when the rules of practice applying to animal-drawn conveyances were discarded, and the problem of motor vehicle design studied from an entirely new angle. The same is true of motorcycle development, because, while undoubtedly the bicycle industry contributed much to the first motorcycle designers, there is now a tendency to depart from the rules of practice found desirable in bicycle construction and to base motorcycle design upon entirely new principles which apply only to self-propelled vehicles.

The modern motorcycle, therefore, may be considered more of an automobile than a bicycle, because in the latest forms we have practically all of the features found in automobile construction. The motorcycle of to-day uses a free engine clutch and change speed gearing, a positive power transmission system and forms of power plant not unlike those used in automobiles. The general construction throughout is stronger and heavier, and larger tires are used. Spring forks and spring frames contribute much to the comfort of the rider, and are really developed from the automobile, which always has carried the load on resilient members, whereas the majority of bicycles depended solely on pneumatic tires to cushion the road shocks. The general rules upon which modern motorcycles are based are those of automobile design rather than the bicycle art, and this is the best insurance of reliability and efficiency that the motorcyclist of to-day has. So long as the development of the motorcycle follows lines that have been demonstrated to be correct in automobile practice, though, of course, changed in detail to make them suitable for the lighter con-

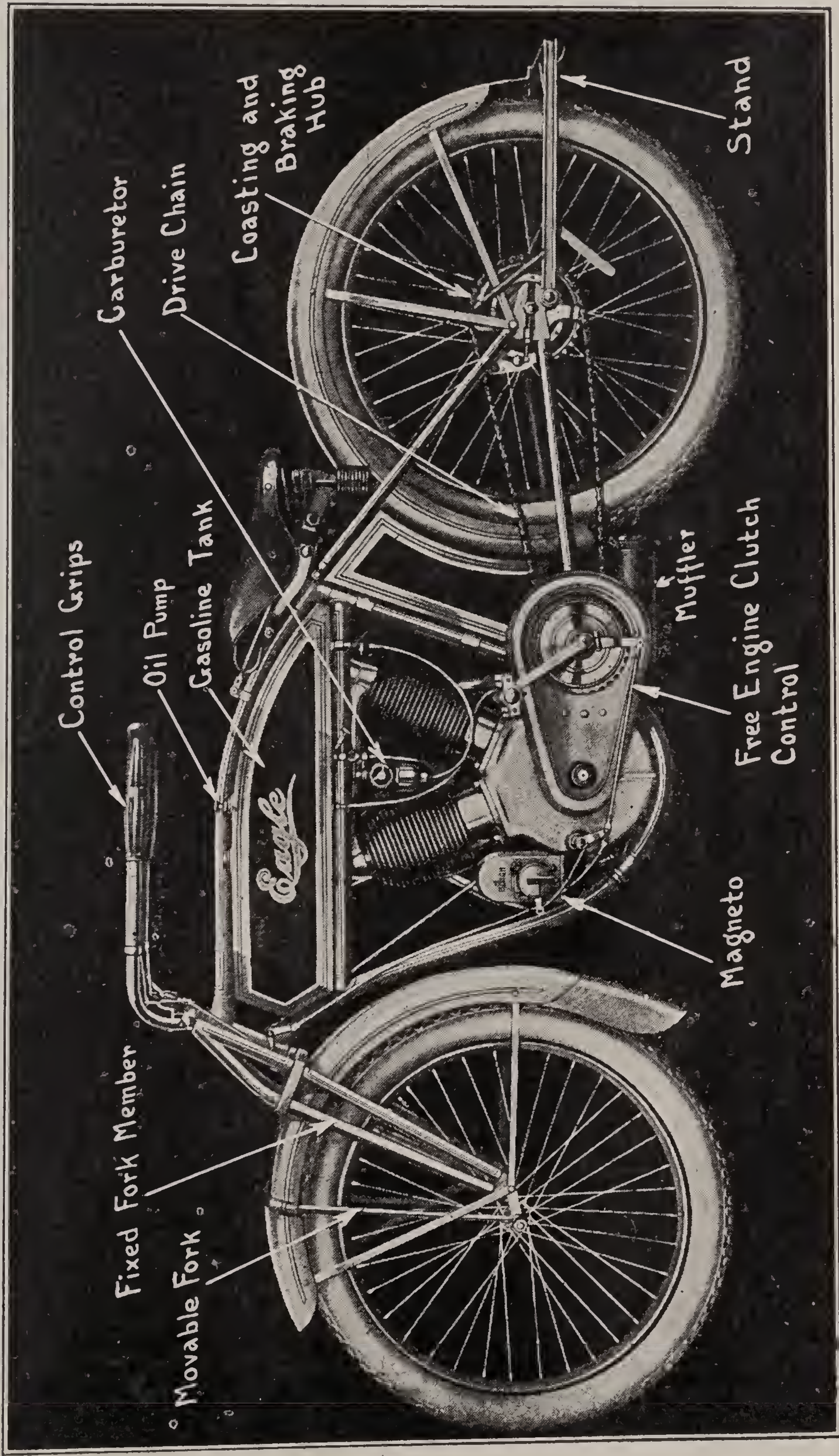

Fig. 29.—Side View of the Eagle Chain Drive Twin Cylinder Motorcycle.

struction, we can hope for material progress and refinement and perhaps the attainment of practical perfection.

The Modern Motorcycle, Its Parts and Their Functions.— Before describing the construction or features of design of motorcycle components, it will be well to outline the principal parts of the motorcycle, and describe their functions so the matter that follows will be intelligible to the non-mechanical reader who is not experienced with the motorcycle mechanism. The foundation of any form of vehicle must necessarily be a frame to which the various parts are attached and which also serves to join the front and rear wheels on which the weight is carried. In general aspect, the frame of the conventional form of motorcycle does not differ from that of the bicycle, though in some constructions a departure is made in utilizing springs as a portion of the framework. This is true of the machine which is shown at Fig. 28 with all important parts clearly outlined. One important difference between the motorcycle frame and that of the bicycle is the use of heavily reinforced tubing, and a departure from the usual diamond frame structure. The lower diagonal bar which goes to the crank-hanger of the motorcycle is often in the form of a loop in which the motor is supported. To provide greater strength than would be secured by but one tube at the top of the frame, practically all motorcycles have two tubes which extend from the steering head to the seat-post mast or tube. In order to obtain a low saddle position, the top frame tube drops appreciably at a point about one-third of its length away from the seat post. The space between the frame bars is usually occupied by fuel and oil tanks.

Next in importance to the frame structure, which includes the wheels, handle bars, saddle, mud guards, luggage carrier, rear wheel stand and foot rests as well as the frame itself is the power plant, and then comes the transmission system. The power plant is composed of a gasoline engine and a number of auxiliary devices upon which its action depends. The driving system includes the clutch, the variable speed gearing and the method of final drive. The direction of travel of a motorcycle is controlled in the same manner as that of a bicycle as the front wheel is mounted in a fork member swiveled in the steering head of the frame. The fork stem is usually provided with ball-bearings so it will turn easily, and the long leverage ob-

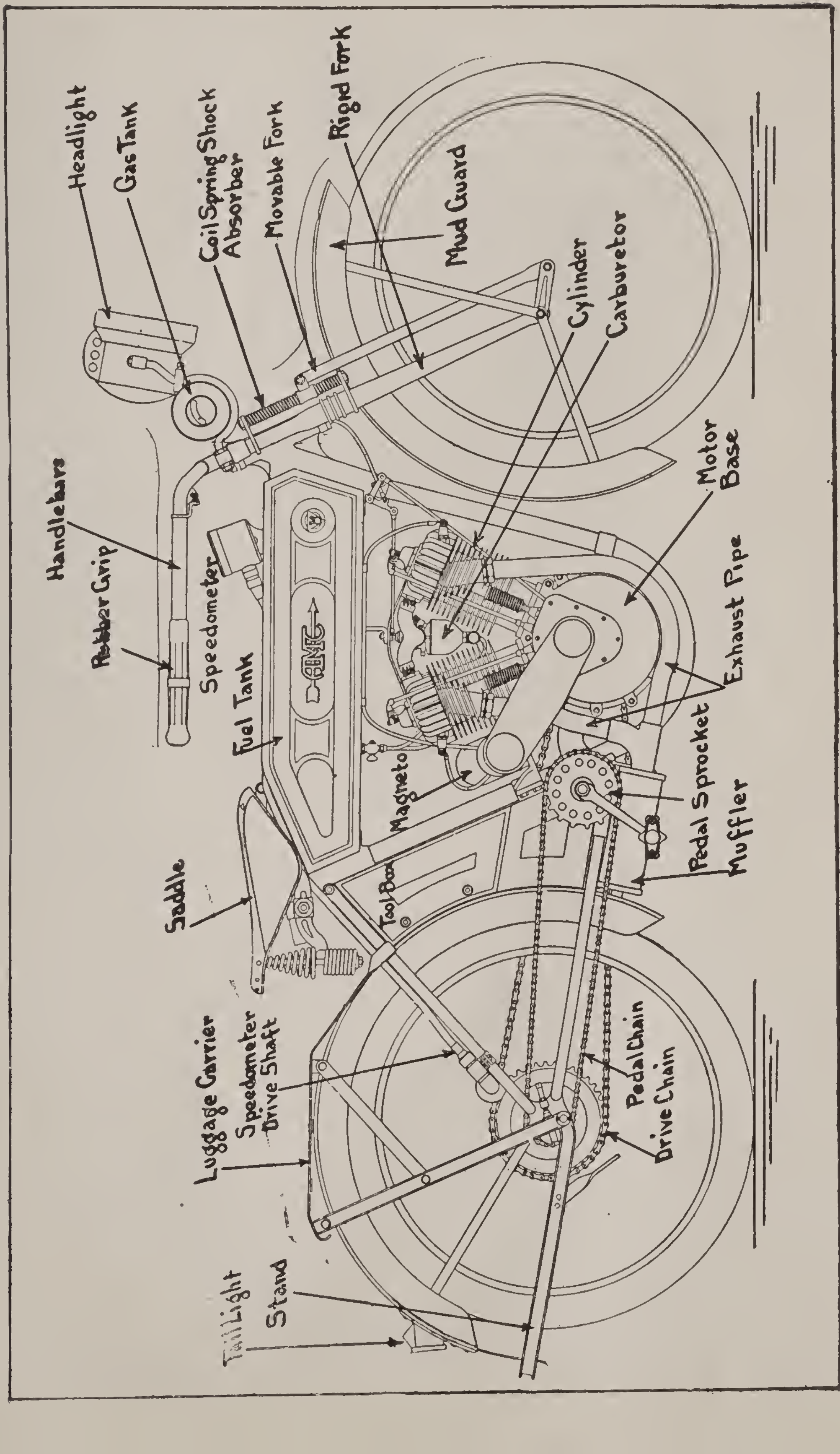

Fig. 30.—The AMC Twin Cylinder Motorcycle With Full Equipment.

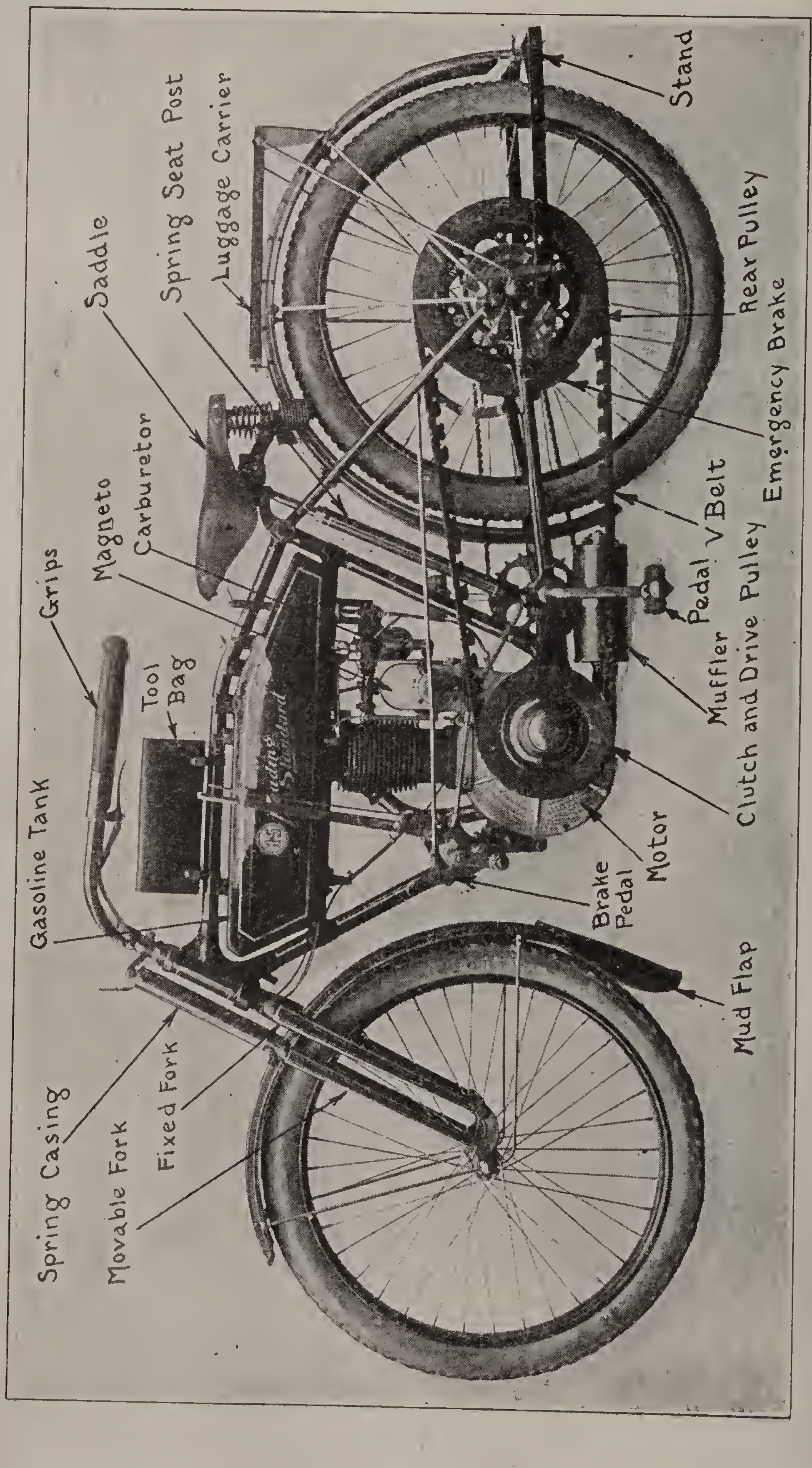

Fig. 31.—Showing Principal Parts of the Reading-Standard Motorcycle, a Representative American Design.

tained by the conventional handle bars insures positive control of the front wheel under any road condition. In order to make for easier riding, the front wheel is carried in a supplementary movable fork member which is attached to links extending from the fixed fork at its lower end and to a laminated leaf spring at its upper end. The base portion of the spring is securely attached to the fixed fork member so that while the front wheel is free to move up and down under the influence of road irregularities, the main stress is taken by the fixed fork member which is capable of only the oscillating motion necessary to steer. The rear end of the frame of the machine shown

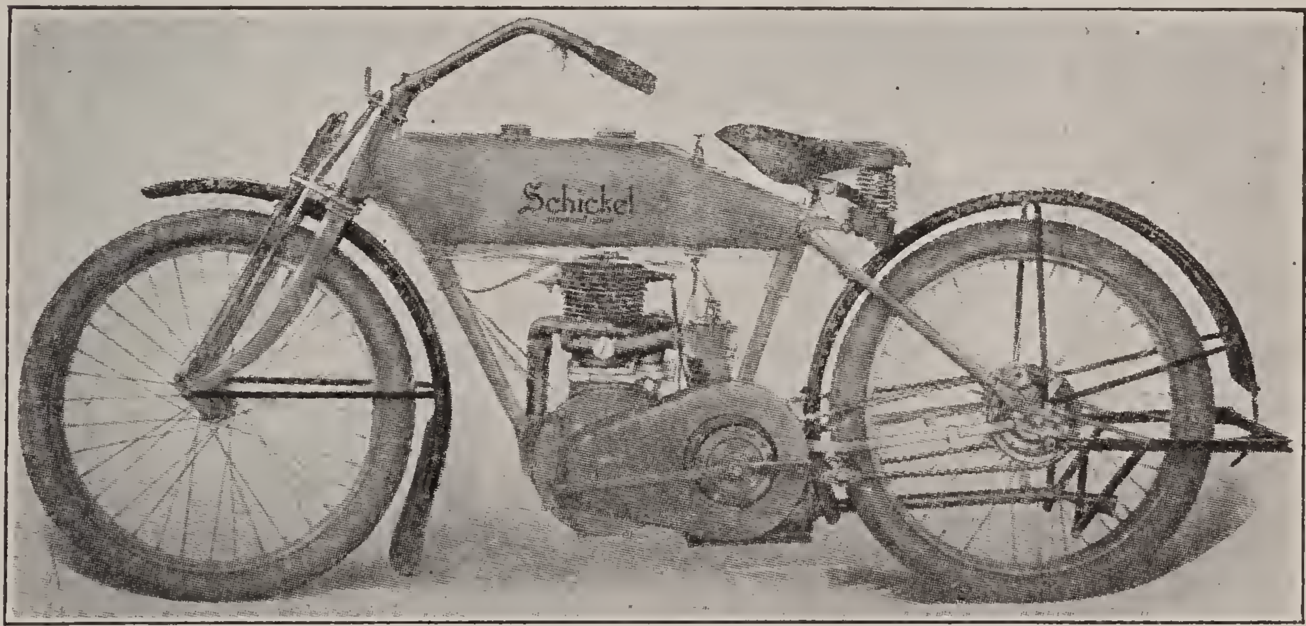

Fig. 32.—The Schickel Motorcycle is a Distinctive Design Employing a Two-Cycle Power Plant.

at Fig. 28 is also carried by a leaf spring and the rear wheel is mounted in a movable fork member that operates in just the same way as that at the front end.

The power of practically all motorcycles is derived from burning gasoline vapor in the cylinders of a small heat engine which is termed a gasoline motor on account of having been designed primarily for use with that fuel, though at the present time these engines will work on practically any hydrocarbon liquid. Grouped with the motor are the auxiliary devices consisting of a carburetor to supply the explosive vapor to the cylinders and a magneto which furnishes the electrical energy used for exploding the gas in the combustion chambers. The

fuel tank, oil pump, and oil tank may also be considered part of the power plant. In the machine shown, the power of the engine is delivered from a small sprocket on the motor crankshaft to a large sprocket forming a part of a clutch casing. The driven members of the clutch are attached to a small sprocket, which in turn delivers its power to a larger member attached to the rear-wheel hub. The clutch is a simple device used to disconnect or connect the engine power to the rear wheel at the will of the rider. If the clutch is out, the engine will operate without moving the rear wheel, though if the clutch parts are in engagement the power will be delivered from the engine crankshaft to the rear wheel, and the engine cannot operate without producing a forward motion of the machine to which it is attached. The wheels used on a motorcycle resemble very much, in general appearance, those commonly employed on bicycles. The rims are heavier and made of steel, while the spokes are of much greater strength to sustain the greater load. The tires are of the double-tube form universally used in automobile and motorcycle practice in which the inner air tube of very flexible rubber is protected from abrasion and depreciation incidental to road contact by a tougher, stronger, but less resilient casing or shoe. The general appearance of motorcycles of various designs and the relation of important components to each other will be readily ascertained by careful examination of the illustrations Figs. 28 to 39, inclusive.

General Characteristics Common to all Forms.—While motorcycles may differ from each other in various essentials of design, there are a number of characteristics which are common to all modern forms. Among these may be stated the method of control, the location of the power plant, the general design of the frame, the placing of the rider's seat, and a number of other points of likeness, which can be easily ascertained by inspection. The use of spring forks, and either spring frames or resilient saddle supports, is general, because the rider demands these refinements at the present time. No matter what form of final driving system is used, the modern machine is not complete without the free engine clutch or variable speed gear, and in most forms these two are provided in one unit. Machines that are built in America follow certain general features which are common to all, and are readily distinguishable from machines of foreign design

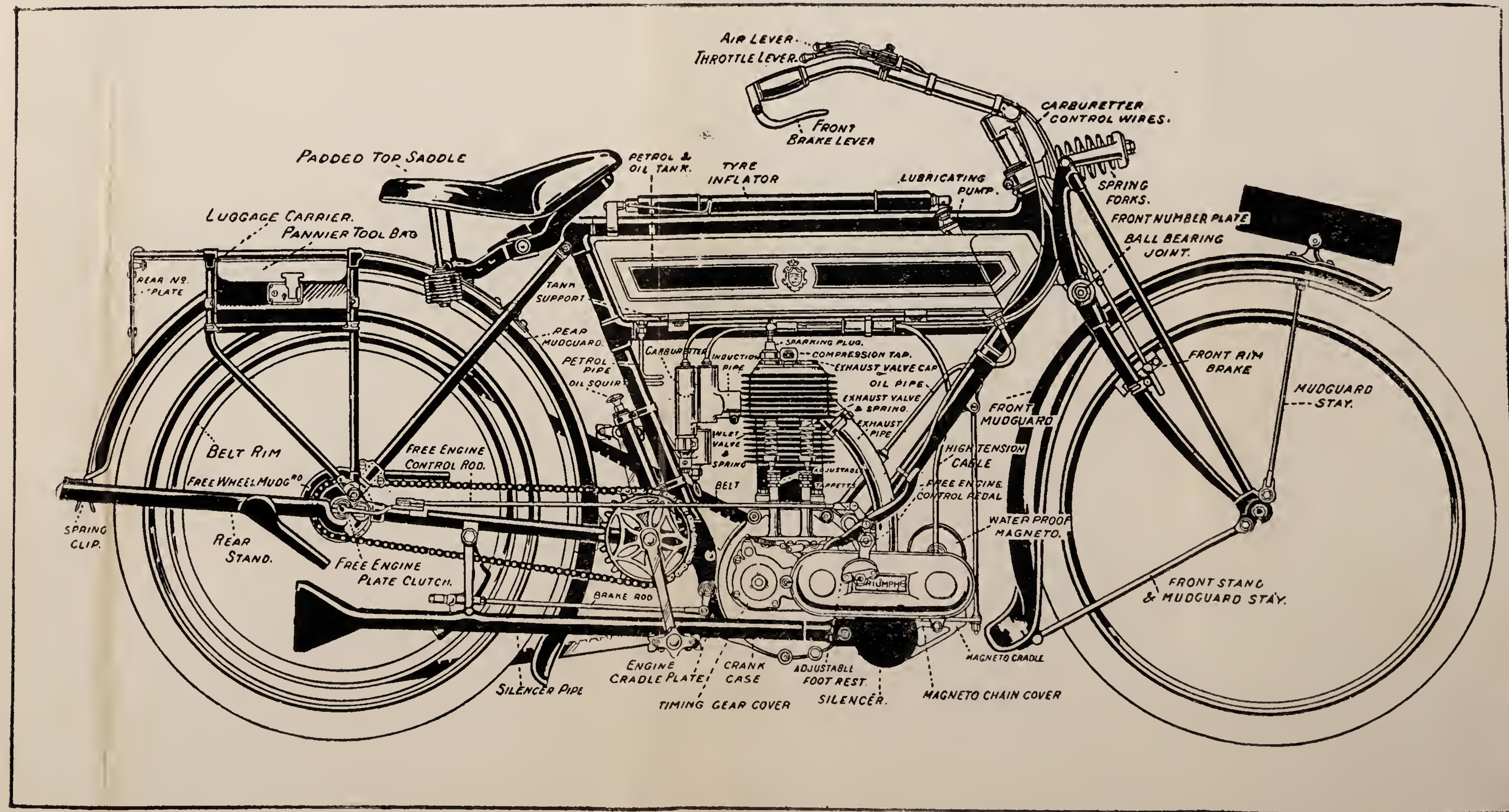

Fig. 33.—Showing the Important Parts of the Triumph Single Cylinder Motorcycle, a Typical English Design.

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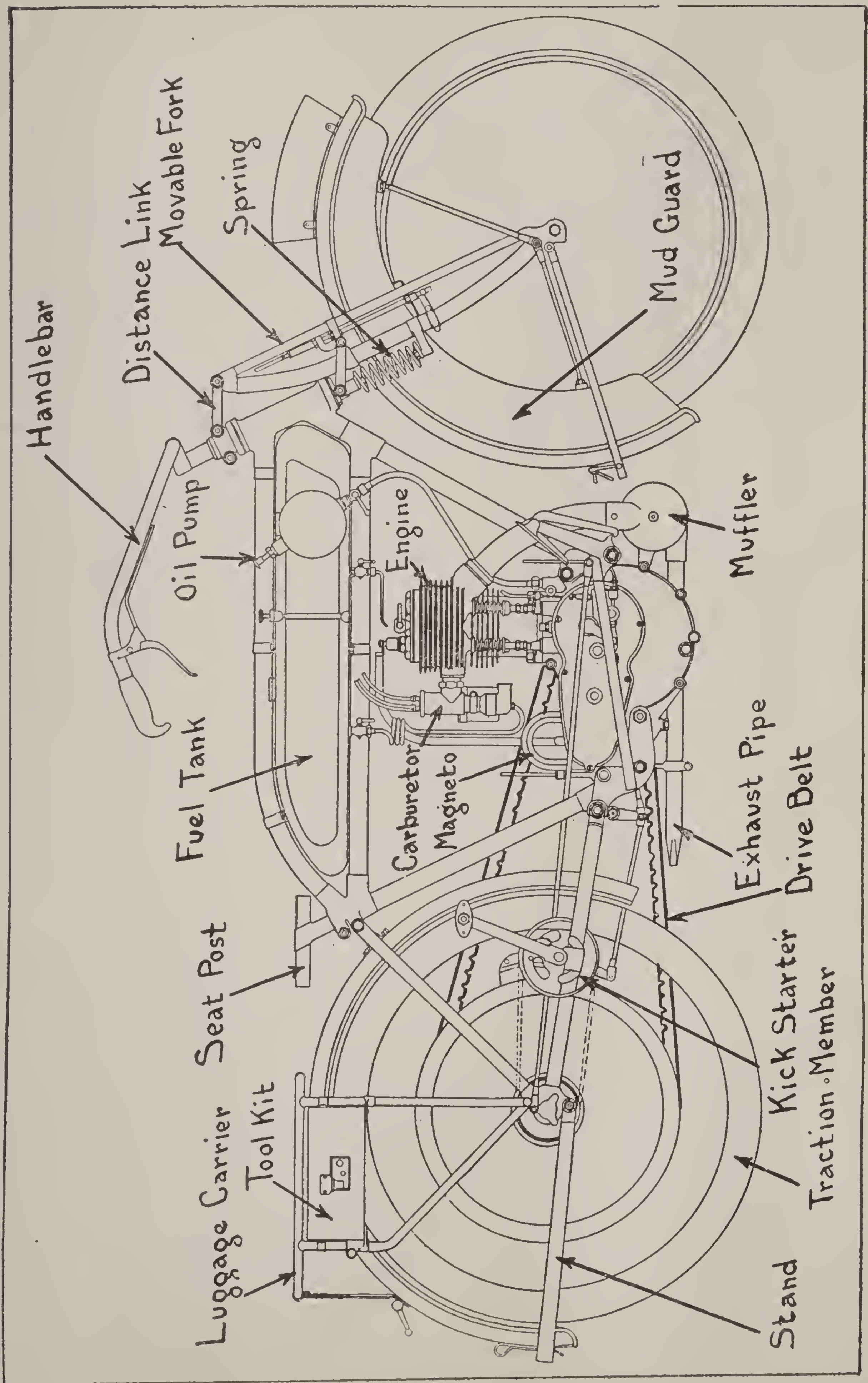


Fig. 34.—Side View of Single Cylinder Motorcycle of English Design With Important Parts Marked For Easy Identification.

which, in turn, have other peculiarities of construction which are distinctive. It is the general opinion of those versed in motorcycle practice that the American machine is much simpler in appearance and much easier to control, and withal fully as efficient as the more complicated foreign designs.

Some Modern Motorcycle Designs.—The illustration at Fig. 29 depicts a successful American motorcycle which has a particularly pleasing appearance. It is provided with a twin-cylinder power plant, and utilizes double chain drive. It incorporates the modern improvements such as spring forks and spring seat post, a free engine clutch, and handle bar control, as not only is the motor speed capable of being varied by the control grip, but the clutch action as well. The wheel base is sufficiently long to insure easy riding, the power plant is carried low to promote stability, and large tires make for easy riding and for minimum depreciation.

The machine shown at Fig. 30 is another American design which is shown fully equipped with various necessary accessories. An efficient single cylinder machine employing a novel system of transmission is shown at Fig. 31. Belt drive is employed, though the arrangement of the under-geared clutch and drive pulley permits the use of a large driving member, which is much more favorable to efficient power transmission by belt than the smaller pulleys attached directly to the engine crankshaft. The machine at Fig. 32 is a distinctive American design employing a single-cylinder, two-cycle engine as a source of power. This is practically the only motorcycle on the American market equipped with a two-cycle power plant. There are a number of other distinctive features such as the spring fork construction and the use of a large hollow aluminum casting which not only acts as a fuel container but which also serves as the main member of the cycle frame, inasmuch as it includes the steering head at the front end and the seat-post supporting tube at the rear.

The machine depicted at Fig. 33 is a representative English design and is a motorcycle that has received wide application abroad. If one compares the general construction of this design with the American machines, it will be noted that the latter are much simpler in appearance, on account of concealed control members for one thing, and the elimination of the front rim brake and its necessary mechan-

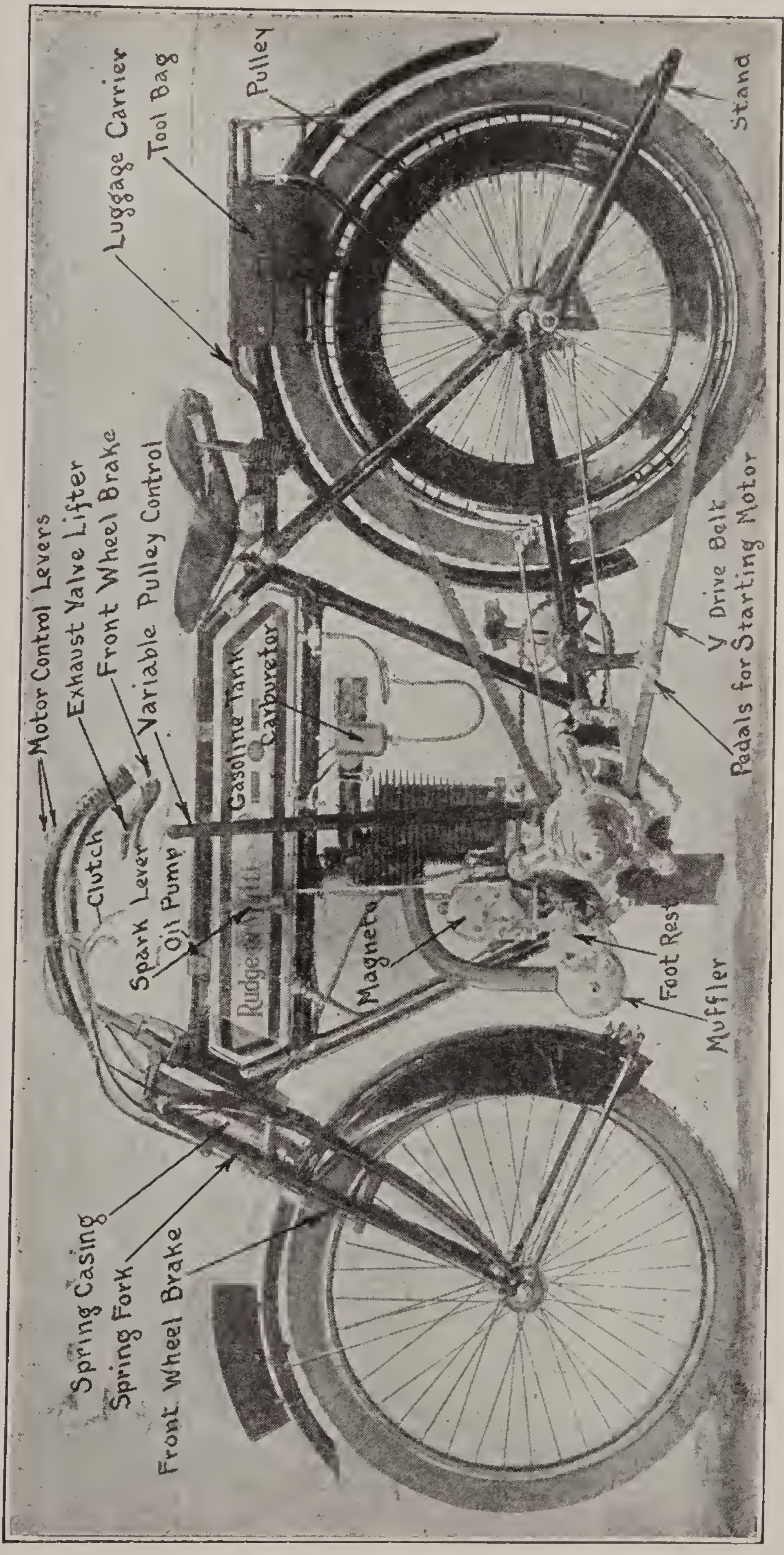


Fig. 35.—The Rudge-Multi Single Cylinder Motor cycle.

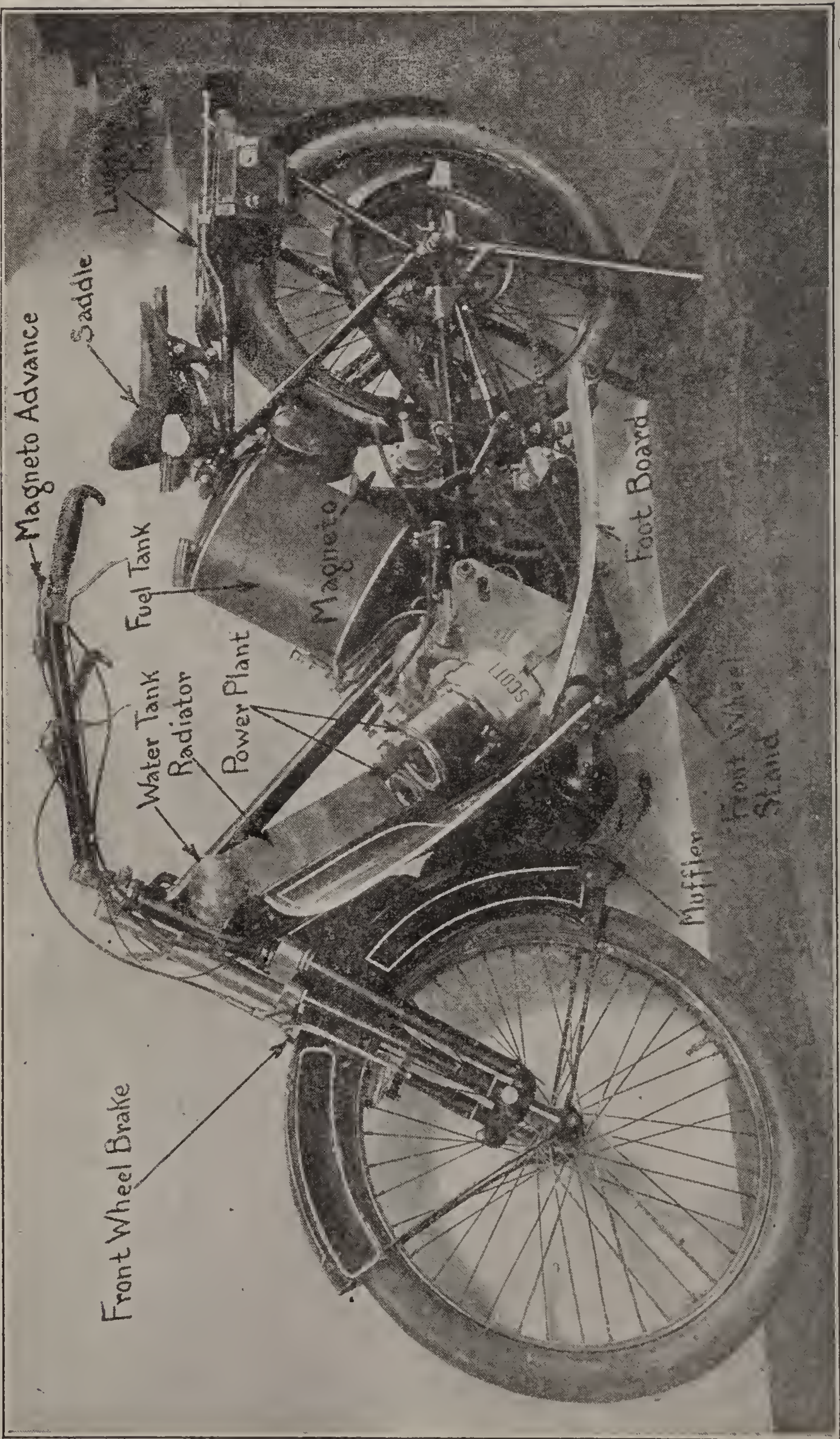


Fig. 36.—The Scott Two Cylinder Motorcycle, an English Design That Incorporates Many Distinctive Features. Such as a Water-Cooled Two Stroke Motor and Open Frame.

ism, as well as a simpler design of spring fork. While the foreign machines are unconventional to American eyes, they are very efficient, and for the most part are said to be considerably more economical to operate than our American machines. Owing to the uniformly better roads found in England and France than are generally provided in this country, the construction is lighter and power plants of lesser capacity are the rule. In the illustration at Fig. 33, all important parts are clearly outlined, and from what has been presented previously it should not be difficult for the reader to understand their functions. Other representative English machines of the single-cylinder type are shown at Figs. 34 and 35.

A machine of very unconventional appearance, yet one that should not be too hastily judged because of the wide variance from our preconceived American notions of what a motorcycle should look like, is shown at Fig. 36. This bristles with original features, and it has demonstrated its practicability beyond doubt by winning one of the most important of all English motorcycle competitive events, the Tourist Trophy race, for two years in succession. The power plant is a two-cylinder, two-cycle, water-cooled motor which furnishes the same steady pull as a four-cylinder, four-cycle with a materially diminished number of working parts. It is mounted on the bottom frame tube with the cylinders inclined toward the steering head. The cooling water is carried in a combined water-tank and radiator which is placed above and forward of the engine cylinders and just back of the steering head. The frame is a peculiar open girder construction, and it is claimed that the elimination of the top frame tube makes it very easy to mount or dismount from the machine. No pedals are provided, as the engine is started with a hand crank in the same manner as an automobile motor, and as a two-speed and free engine gear is provided, the motorcycle may be readily started from a standstill. The fuel tank is of approximately oval section, and at the back end it provides a support for the rear fork stays to which the front end of the luggage carrier and the saddle supporting member are attached. The machine is provided with foot boards and a front wheel stand, following general European practice. One point that will impress the American motorcyclist is the multiplicity of control levers mounted on the handle bars, and the general appearance of

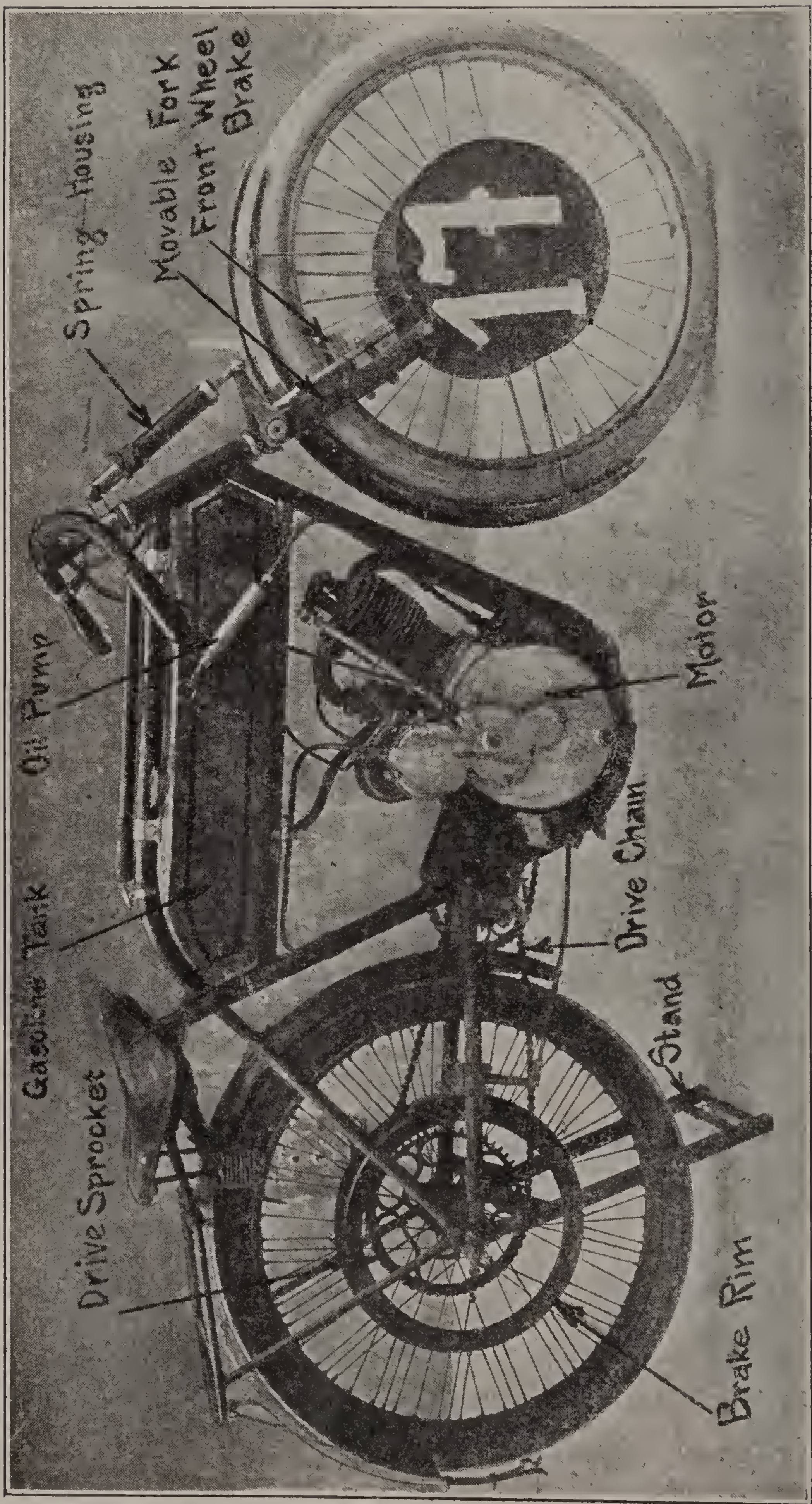


Fig. 37.—An Example of French Motorcycle Design.

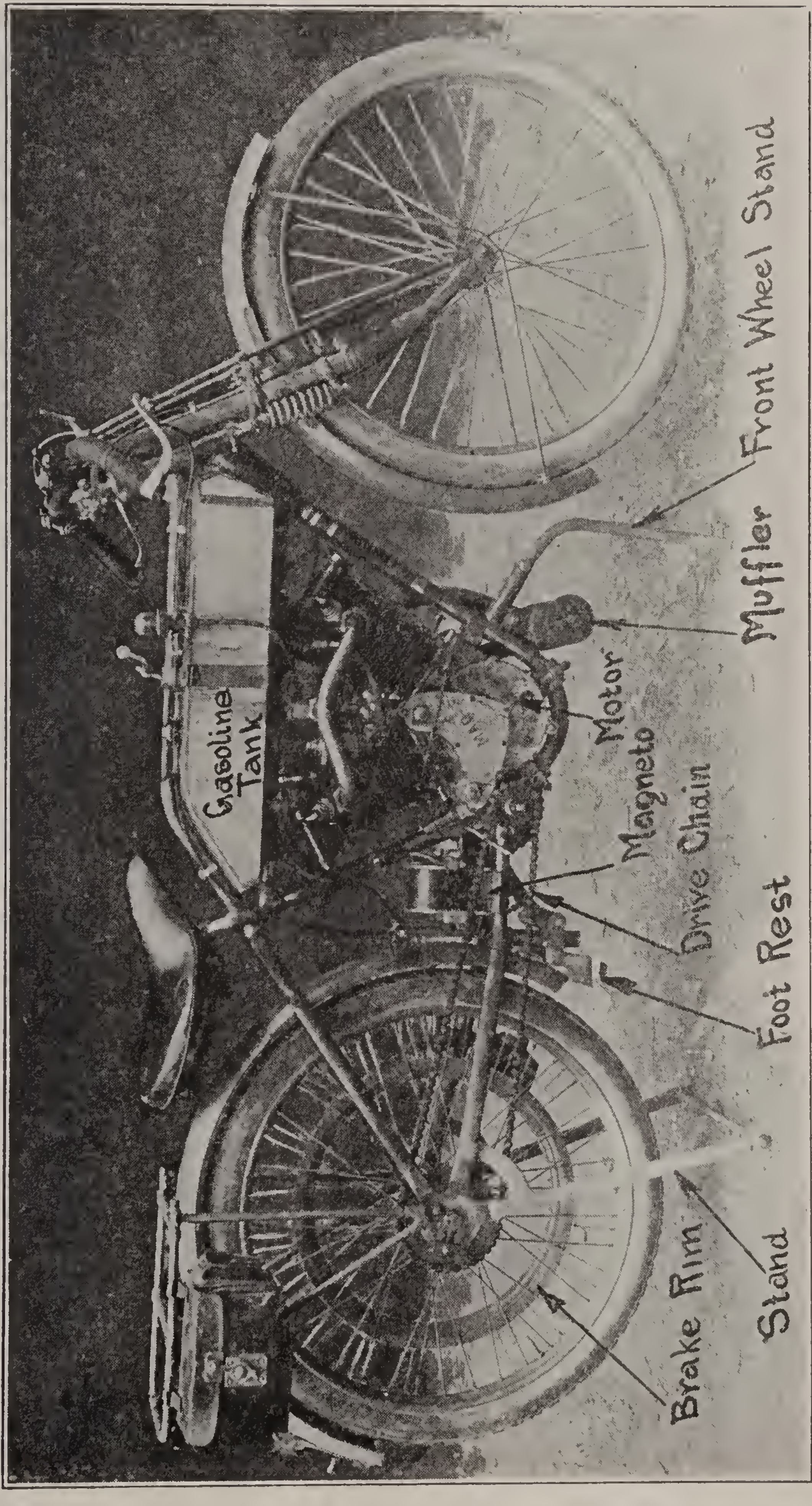


Fig. 38.—The Clement Twin Cylinder Motorcycle, Another Example of French Design.

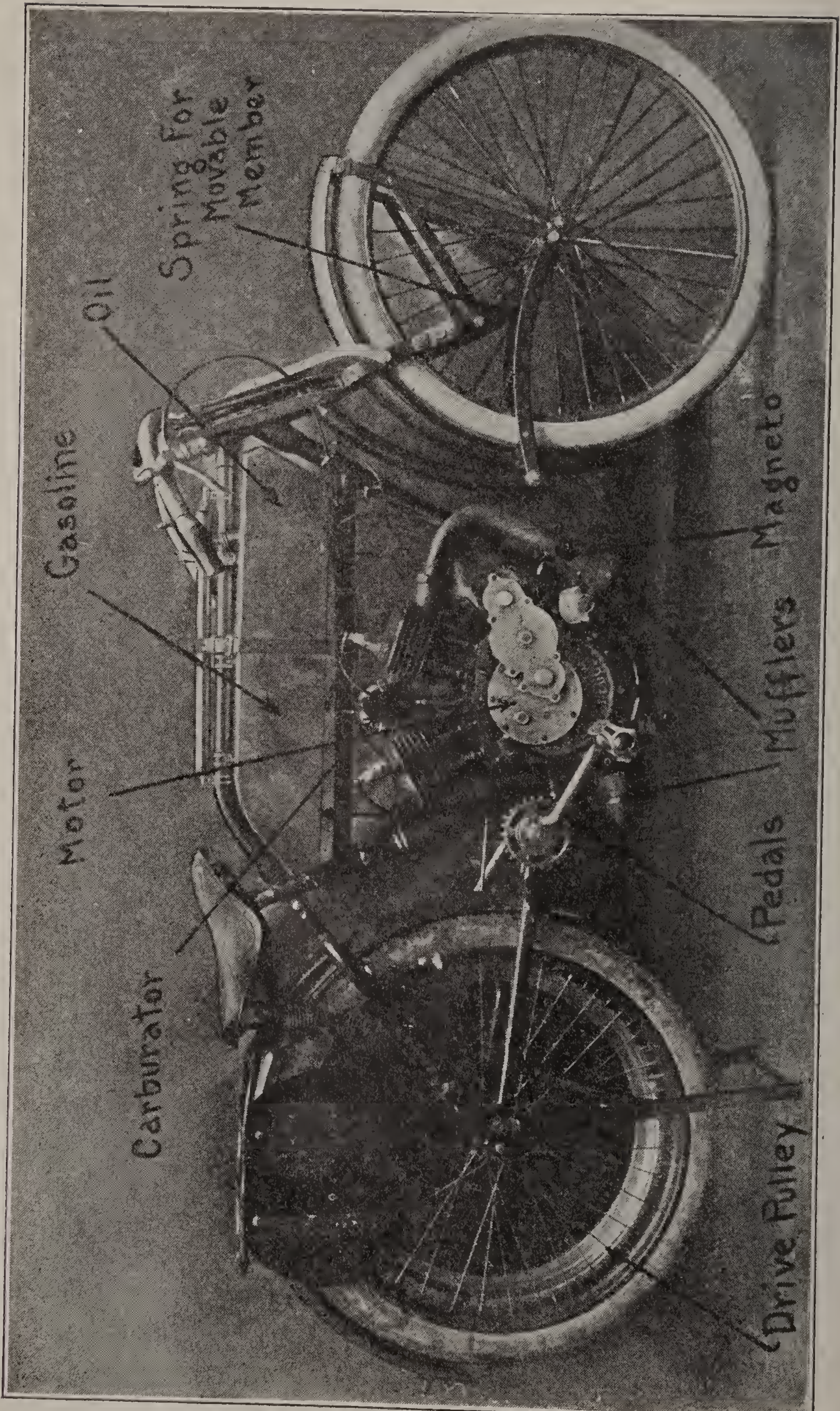


Fig. 39.—Peugeot Twin Cylinder Model, One of the Leading French Motorcycles.

complication is much intensified by the number of control wires extending from the handle bars to the various portions of the mechanism they are intended to regulate.

The motorcycles shown at Figs. 37 to 39, inclusive, are of French design, and it will be apparent that these follow English practice more than American, though they are not as well finished in detail as either the English or American machines. A single-cylinder motor with a double chain drive is utilized for power in the motorcycle shown at Fig. 37, which is the simplest of the three forms. Two-cylinder motors are used on the remaining two designs, one using a single chain final drive, while the other employs a V-belt. The spring fork of the Clement machine, shown at Fig. 38, is of English design, though the similar members of the other two are undeniably of French derivation. The utility of the front wheel stand which is provided on a number of the foreign machines is clearly outlined at Fig. 38, and it will be apparent that it is possible to remove both front and rear wheels from the machine in question without depriving it of means of support that will keep it upright, and in the proper position for the easy replacement of the wheels. This is a valuable feature, as it is often desirable to rotate the front wheel as when adjusting the wheel bearings, testing the wheel for truth of running and in making tire repairs. If both front and rear wheels are removed from an American machine, there is nothing to support the front end, and it requires considerable patience to find the necessary odds and ends such as cobbles, bricks or pieces of wood to support the motor weight by filling up the space between the bottom of the frame and the ground, in order to raise the front wheel clear for removal or to keep the frame in proper position for wheel replacement. In essentials, the English and French motorcycles do not differ from those we are familiar with, though, of course, one must expect to find the individuality of the foreign designer expressed in some ways. It is apparent to anyone who will consider the merits of the various designs shown, without prejudice, that the American designer produces neater motorcycles than his foreign contemporary, and machines that are really more practical because of the simplicity of control and the general strength of parts demanded by our severe operating conditions.

CHAPTER II.

MOTORCYCLE POWER PLANT GROUP.

The Gasoline Engine and Auxiliary Devices—Features of Two Main Engine Types—Operating Principles of Four-Cycle Engines—How Two-Cycle Engine Works—Methods of Figuring Rated Horse-Power—How Actual Horse-Power is Tested—Relation of Torque to Horse-Power and Its Meaning—Reason for Cooling Engine—Air of Water Cooling—Efficiency of Air-Cooled Motors—Methods of Air Cooling—Water-Cooling Methods—Features of One-Cylinder Motors—Advantages of Multiple-Cylinder Forms—Types of Two-Cylinder Power Plants—Four-Cylinder Forms—Power Plant Support and Location—Motorcycle Engine Parts and Their Functions.

The Gasoline Engine and Auxiliary Devices.—To the uninformed, a motorcycle or automobile power plant seems to consist essentially of a gasoline motor, but to the initiated it is known that while the internal combustion engine is a very important component of the power plant it is of little more value than so much metal when one of the important auxiliary devices which are distinct in construction from the engine fails to function properly. A complete motorcycle power plant with all auxiliary devices clearly outlined is illustrated at Fig. 40, and it will be apparent that in addition to the gasoline engine various other devices are included in the power-producing assembly.

In the first place, it is necessary to provide some method of storing the fuel, or a gasoline tank, and then of supplying it to the cylinder in the form of an inflammable gas. The latter is the function of the carburetor to which the gasoline from the tank is first directed. This device mixes the gasoline vapor and air in proper proportions, and supplies the vapor to the inlet valve cage of the motor. Some means of exploding the charge of gas in the cylinder is necessary, so an ignition system is used which is composed of a high-tension magneto, a suitable length of conductor and a spark plug in the cylinder. The

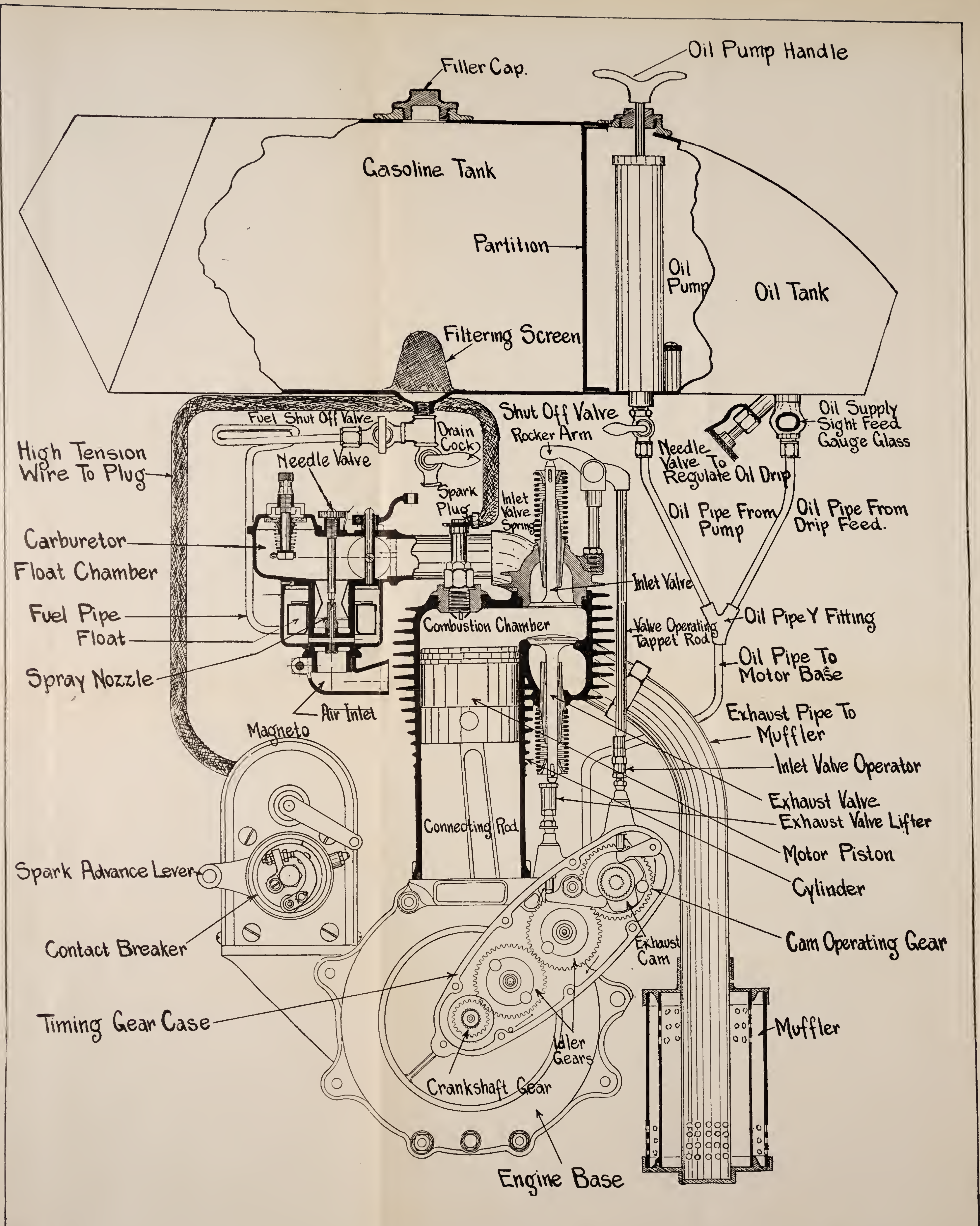


Fig. 40.—Complete Motorcycle Power Plant, Showing the Relation of All Auxiliary Components to the Gasoline Engine.

wire conveys the electricity generated by the magneto to the spark plug inserted in the combustion chamber. In order to prevent annoyance, due to noisy operation, a silencing device or "muffler" is attached at the end of the pipe through which the exhaust gases leave the engine cylinder. As it is important that any piece of machinery should be properly oiled, if it is desired that it work efficiently, a portion of the gasoline tank is partitioned off to form a supplementary oil tank to hold an adequate supply of lubricant. Some means of supplying the oil to the engine must be provided so, in the simple form of power plant outlined, one may inject the oil directly to the engine base through the medium of a hand-operated oil pump. This may be either built into or attached to the side of the tank. Another means of supplying oil besides the hand-pump is provided on most motorcycle power plants, and this may be either a mechanically operated pump or a gravity sight-feed system in which the oil flows to the engine because of its weight. The amount of lubricant is regulated by a suitable needle valve that controls the passage leading from the oil tank to the gauge glass chamber. In addition to the gasoline engine itself, it is therefore necessary to include a carburetor or gas maker, a magneto or spark producer, a muffler to silence the exhaust gases, some system of lubrication, and suitable containers for fuel and lubricating oil. Another type of power plant with all parts clearly shown, excepting the fuel and oil containers, is presented in Fig. 41.

Features of Two Main Engine Types.—Two types of gasoline engines have been applied generally to furnish power for transportation purposes. These differ in construction and operating cycle to some extent, though in all forms power is obtained by the direct combustion of fuel in the cylinders of the engine. In all standard engines, a member known as the piston travels back and forth in the cylinder with what is known as a reciprocating motion, and this in turn is changed into a rotary motion by suitable mechanical means to be described fully in proper sequence. Gas engines may operate on either the two-cycle or four-cycle principle, the former being the simplest in action, though the latter is easiest to understand.

The sectional view of a two-cycle engine depicted at Fig. 45 shows the three moving parts employed. The gas is introduced into the cylinder, and expelled from it through ports cored into the cylinder

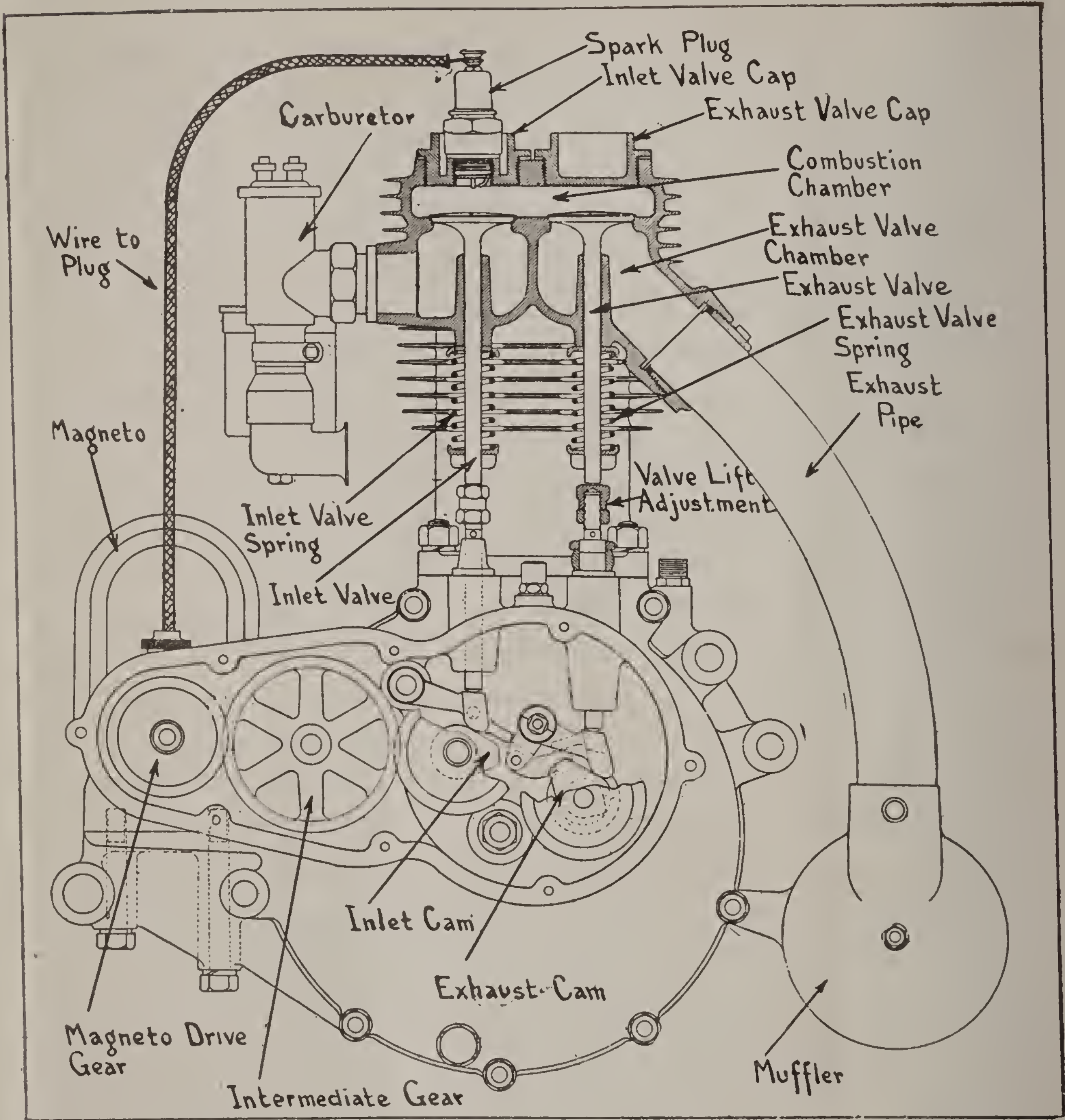


Fig. 41.—Complete Single Cylinder Motorcycle Power Plant of English Design, Showing Location of Carburetor, Magneto and Muffling Device.

walls, which are covered by the piston at a certain portion of its travel and uncovered at other portions of the stroke. The three moving parts are the piston, connecting rod and crankshaft. If this type of power plant is compared with the four-cycle engine shown at Fig. 42, it will be apparent that it is much simpler in construction.

In the four-cycle engine, the gas is admitted into the cylinder through a port at the head closed by a valve, while the exhaust gas is expelled through another port controlled in a similar manner.

These valves must be operated by mechanism distinct from the piston. In addition to the three main moving parts used in the two-cycle engine, there are a number of auxiliary moving members that are part of the valve-operating mechanism. The four-cycle engine is more widely used because it is the most efficient type. The two-cycle engine is simpler to operate and very smooth running, but it is not as economical as the four-cycle because a portion of the fresh gas taken into the cylinder is expelled through the open exhaust port with the burnt gases before it has a chance to ignite. As the four-cycle engine is more generally used, its method of operation will be described first.

Operating Principles of Four-cycle Engines.—The action of the four-cycle type will be easily understood if one refers to the illustrations at Figs. 42 and 43. It is called a four-stroke engine because the piston must make four strokes in the cylinder for each explosion or power impulse obtained. The principle of a gas engine is similar to that of a gun, i. e., power is obtained by a rapid combustion of some explosive or other quick-burning substance. The bullet is driven out of a gun barrel by the powerful gases liberated when the charge of powder is ignited. The piston of a gas engine is driven toward the open end of a cylinder by the similar expansion of gases resulting from combustion.

The first operation in firing a gun or securing an explosion in the cylinder of a gas engine is to fill the combustion space with combustible material. The second operation is to compress this, and after compression, if the charge is ignited, the third operation of the cycle will be performed. In the case of the gun, the bullet will be driven out of the barrel, while the piston of the gas engine will be forced toward the open end of the cylinder. As the bullet leaves the mouth of the gun, the barrel is automatically cleared of the burnt powder gases which escape to the outer air because of their pressure. The gun must be thoroughly cleared before the introduction of a new charge of powder. In a gas engine, the fourth operation or exhaust stroke is performed by the return stroke of the piston.

The parts of a simple engine have been previously indicated, and, in order to better understand the action, it will be well to consider briefly the various parts and their functions. The cylinder is an im-

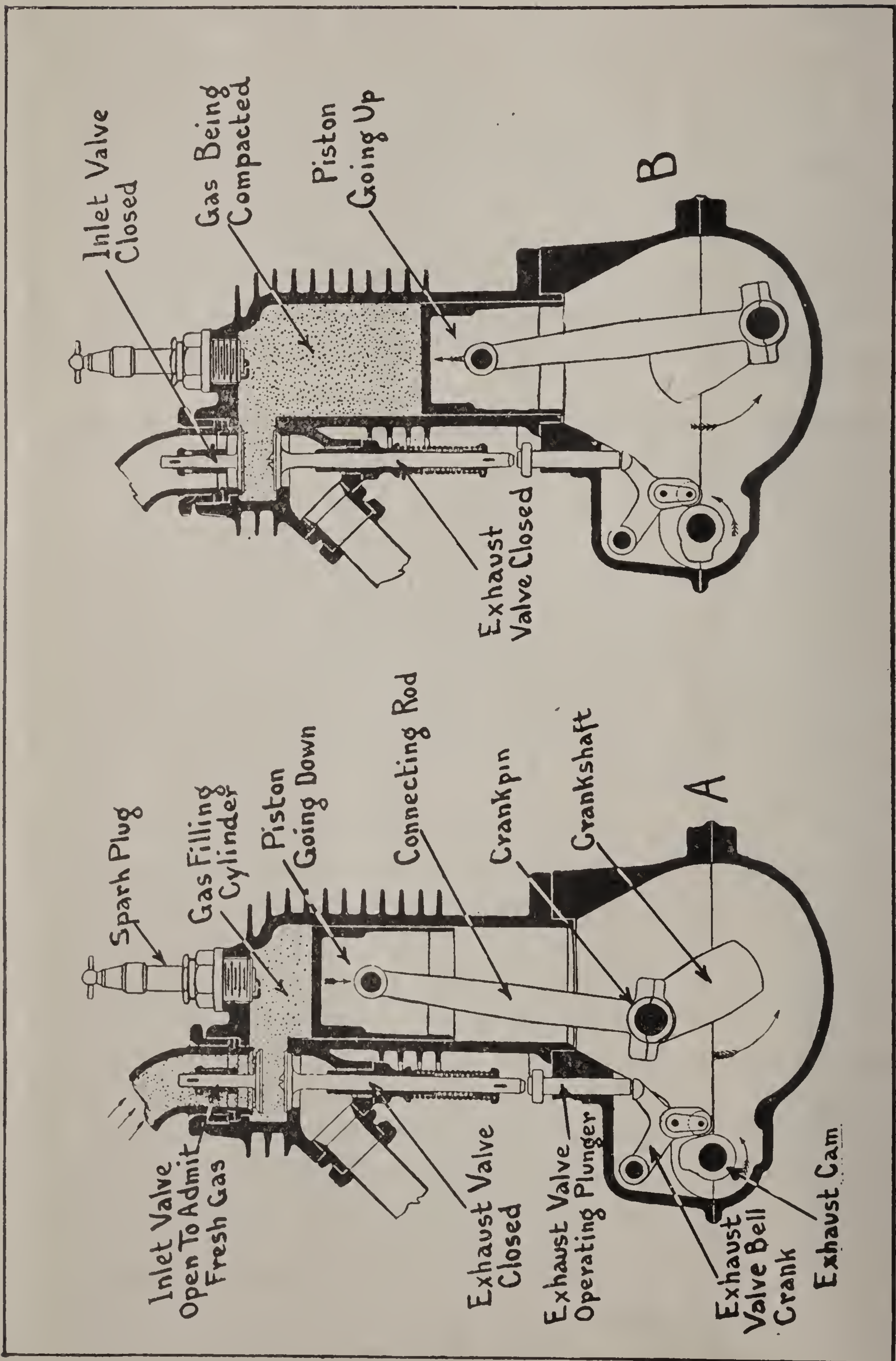


Fig. 42.—Diagrams Illustrating Action of Four-cycle Motorcycle Power Plant. A—Piston Starting on Induction Stroke. B—Piston Starting on Compression Stroke.

portant member because it is in this portion that practically all the work is accomplished. The cylinder is provided with three ports at the combustion end, one through which the gas is admitted, controlled by an inlet valve, another through which the burnt gas is expelled, closed by the exhaust valve, and the third in which the spark plug used to ignite the compressed gas is screwed. The reciprocating motion of the piston, which is the member moving up and down in the cylinder, is transformed into a rotary motion of the crankshaft by a connecting rod and crank pin.

In the simple engine shown at Figs. 42 and 43, the inlet valve is an automatic one, while the exhaust member is raised from its seat by a mechanism including the cam-shaft, cam, valve-operating bell crank and plunger. At Fig. 42-*A*, the piston is starting to go down on the first stroke of the four necessary to produce a complete cycle of operations. As the piston descends, it creates a suction in the combustion chamber, the automatic valve is drawn down from its seat and a fresh charge of gas is inspired into the cylinder through the inlet pipe which communicates with the gas-supply device or carburetor. The inlet valve will remain open until the piston reaches the bottom of its stroke. As soon as the pressure inside the cylinder is equal to that outside, which condition obtains as soon as the piston has reached the end of its downward stroke and the cylinder is filled with gas, the inlet valve is closed and the piston starts to return on the next stroke, as shown at Fig. 42-*B*.

As both valves are closed, the combustible gas with which the cylinder is filled is compressed into a much smaller volume. The reason for compression is that any agent which gives out energy through the expansion of gases is rendered more efficient by confining it in a restricted space and directing the whole energy against some one spot. A tuft of guncotton could be ignited while lying loosely in the hand and it would burn freely but without explosion. If it is confined in a gun barrel and exploded, it will drive the bullet out with a great amount of force, or burst the metal walls of the container. Gasoline vapor and air will ignite and burn freely at atmospheric pressure, and a gasoline engine could be made to run without compression. The expansion of the unconfined gases would not be great enough to do effective work, however, and the fullest efficiency of the

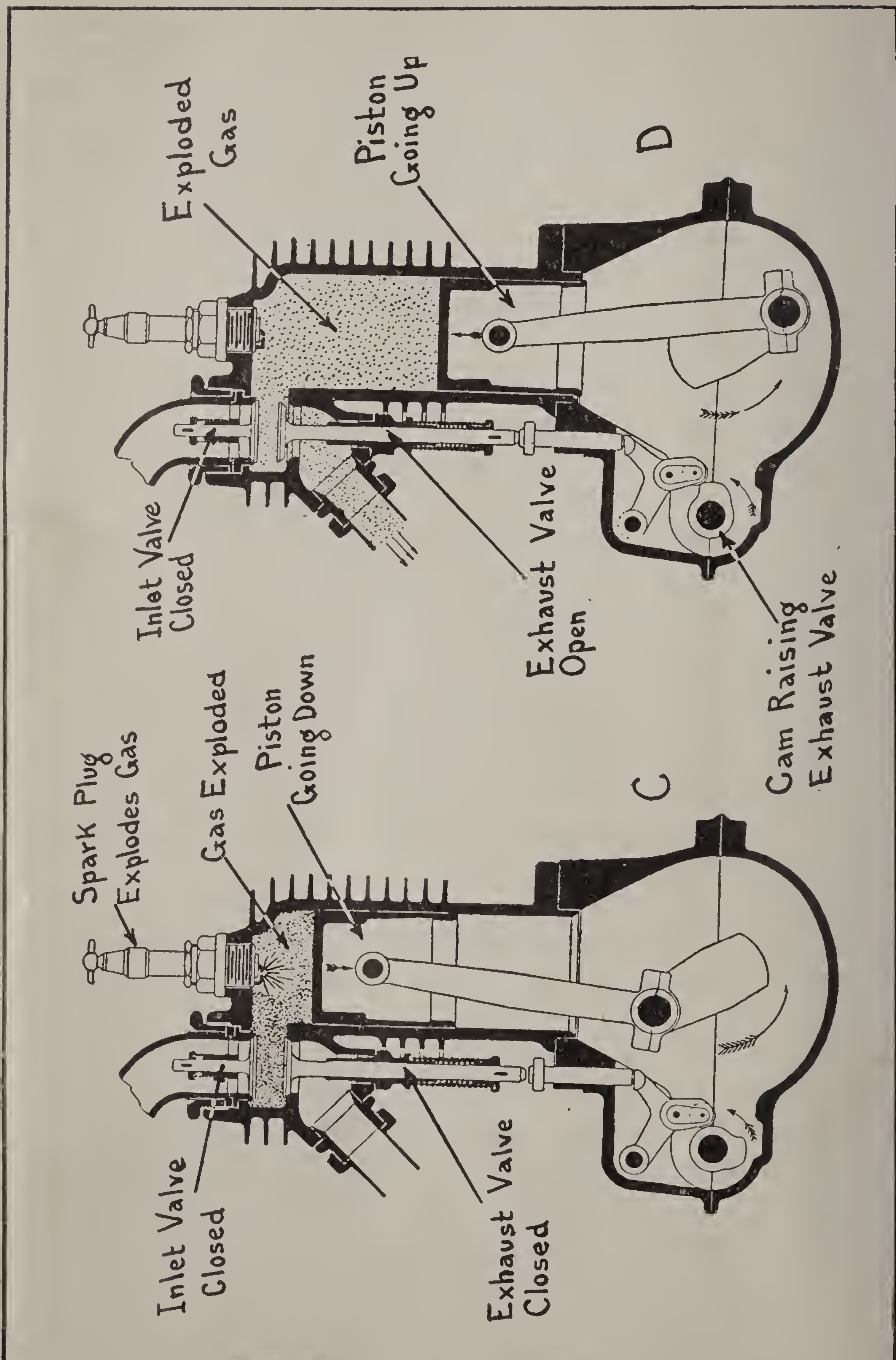


Fig. 43.—Diagrams Illustrating Action of Four-cycle Motorcycle Power Plant. C—Position of Piston at Start of Power Stroke. D—Piston Starting on Scavenging Stroke.

fuel is obtained by compacting it into the smallest possible space and then igniting it at the instant when it is compressed the most.

Any chemical action requires close contact between the materials producing it, if it is to occur under the most favorable conditions. That which occurs when a mixture of gasoline vapor and air are brought into contact with the flame or arc of the electric spark is practically instantaneous if the gases are crowded together. If the gas is not properly compressed, the action becomes more dilatory, extending to a slow combustion wherein the temperature is not raised enough to expand the gases efficiently as the degree of compression is lessened. A good example of slow combustion is the decay of wood, while the phenomenon that we call "burning" may be taken as an illustration of quick combustion. It is said that the same amount of heat is produced by either combustion, but only the latter produces it quickly enough to be noticeable.

The comparatively slow combustion of the gases in the engine cylinder, when at atmospheric pressure would not permit the energy derived from the heat to act all at once. When the gases are compressed, the particles of vapor are in such intimate contact that combustion is practically instantaneous, and the gases give off maximum energy by expanding their utmost, due to the high temperature developed. The piston is also in a position to be acted upon most readily as the force due to pressure of the gas is directly against it and not exerted through a cushion of elastic half-ignited gas as would be the case if the charge was not compressed before ignition.

When the piston reaches the top of its second stroke, the compressed gas is exploded by means of an electric spark between the points of the spark plug, and the piston is driven down toward the open end of the cylinder, as indicated at Fig. 43-*C*. At the end of this down stroke, the pressure of the gases is reduced to such a point that they no longer have any value in producing power. At this time, the cam, which is operated in timed relation to the crankshaft travel, raises the exhaust valve from its seat, as at Fig. 43-*D*, and the burnt gases are expelled through the open exhaust port until the cylinder is practically cleared of the inert products of combustion, the natural scavenging action, due to gas pressure, being assisted by an upward movement of piston. The piston once more begins to descend,

as shown at Fig. 42-*A*, and the inlet valve opens to admit a new charge. The rest of the cycle of operations follow in the order indicated, and are repeated as long as the cylinder is supplied with gas and this is ignited.

When a two-cylinder engine is employed the action is practically the same, except that the two cylinders are accomplishing different operations of the cycle simultaneously. For example, in the engine shown at Fig. 44, which is of the two cylinder V-type so widely used in motorcycle and cycle car practice, we find at *A* that while the piston in the left hand cylinder is going down and drawing in a charge, the piston in the right hand cylinder has just reached the end of its compression stroke, and is starting to go down under the influence of the expanding ignited charge of gas. When the pistons reach the bottom of the stroke, before starting up again it will be seen at *B* that the cylinder on the left hand side is full of fresh gas and the inlet valve is closed, while that on the right side is still filled with the flaming gases due to the previous explosion. The position of the pistons at the end of the next stroke is depicted at *C*. Here the cylinder on the left side, the piston of which has just compressed a charge, has its combustion chamber full of burning gas, while the cylinder on the right side is just being cleared of the inert gases produced by the previous explosion through the open exhaust valve member. At *D*, the beginning of the last or exhaust stroke in the left side cylinder is indicated. As the piston is about to go up and the exhaust valve is opened, the burnt gases can be properly discharged. The right hand cylinder is filling with gas through the open inlet valve as the suction stroke in that cylinder is not yet fully completed.

It will be evident that while the piston in one cylinder is just beginning to go down on an inlet stroke, that in the other cylinder is just completing a compression stroke. When the piston in the left-hand cylinder is just beginning its compression stroke, that in the right-hand cylinder is completing its explosion stroke. When the piston in the left-hand cylinder is being forced down by exploded gas, the similar member of the right-hand cylinder is just finishing its exhaust stroke. When the piston in the left-hand cylinder is starting on its exhaust stroke, that in the right-hand cylinder has just completed its suction stroke. By having two cylinders performing differ-

ent functions simultaneously, it is possible to obtain one explosion for each revolution of the fly-wheel, whereas in a single-cylinder engine it takes two revolutions of the crankshaft to obtain one useful power stroke.

How Two=cycle Engine Works.—The two-cycle engine works on a different principle, as while only the combustion chamber end of the piston is employed to do useful work in the four-cycle engine, both upper and lower ends are called upon to perform the functions necessary to two-cycle engine operation. Instead of the gas being admitted into the cylinder, as is the case with the four-cycle engine, it is first drawn into the engine base, where it receives a preliminary compression, prior to its transfer to the working end of the cylinder.

The views at Fig. 45 show clearly the operation of a two-port, two-cycle engine. Assuming that a charge of gas has just been compressed in the cylinder and that the upward movement of the piston while compressing the gas above it has drawn in a charge through the automatic intake valve in the crank-case, it will be apparent that as soon as the piston reaches the top of its stroke, and the gas has been properly compressed, the explosion of this charge by an electric spark will produce power in just the same manner as it does in the four-cycle motor. As the piston descends, due to the impact of the expanding gases, it closes the automatic inlet valve in the crank-case and compresses the gases confined therein.

When the piston reaches the bottom of the cylinder it uncovers the exhaust port cored in the cylinder wall and the burnt gases leave the cylinder because of their pressure. A little further and the downward movement of the piston uncovers the intake port, which is joined to the crank-case by a by-pass passage, at which time a condition exists as indicated at Fig. 45, B. The piston has reached the bottom of its stroke, and both exhaust and inlet ports are open. The burnt gases are flowing out of the cylinder through the open exhaust port, while the fresh gases are being transferred from the crank-case, where they had been confined under pressure to the cylinder. The fresh gas is kept from passing out of the open exhaust port opposite the inlet opening by a deflector plate cast on the piston head, which directs the entering stream of fresh gas to the top of the cylinder.

As the piston goes back on its up stroke, the exhaust and inlet ports

are closed by the piston wall, and the charge of gas is compressed prior to ignition. As the piston travels up on its compression stroke, the inlet valve in the crank-case opens, due to the suction produced by the piston, and admits a charge of gas through the open crank-case intake port. It will be seen that an explosion is obtained every two strokes of the piston instead of every four strokes, as is the case with a four-cycle engine. In the two-cycle form, one explosion is obtained for each revolution of the crankshaft, while in the four-cycle two revolutions of the crankshaft are necessary to obtain one power impulse.

The operating principle of the three-port two-cycle engine is just the same as that previously described except that the gas from the carburetor is admitted to the crank-chamber through a small port in the cylinder wall, which is open when the piston reaches the top of the stroke. The three-port method of construction makes it possible to dispense with the automatic inlet valve shown in Fig. 45, and an engine of this kind is therefore a true valveless type. The two-cycle motor, while it offers many advantages in theory, has some weaknesses, because if it did not have any disadvantages, it would soon entirely supplant the more complicated four-cycle engine. The two-stroke type has already proven practical in the Scott motorcycle, a British design, and the Schickel motorcycle, an American construction. At the present time, there is considerable interest manifested in this type of power plant in England, and a number of very efficient light-weight machines of two and three horse-power have been evolved that employ small two-cycle power plants. The only form of two-cycle engine to have received any application in motorcycle service is the valveless three-port type. The two-port system has received some application in marine service, but it is not capable of as high speed, and is not apt to function so regularly as the three-port, owing to check valve trouble. In the latter form, all valves are eliminated.

As the exhaust port opens first and closes last, considerable burnt or inert gas will mix with and dilute each new charge, and as the exhaust port is still open after the inlet port closes it is apparent that even the best designed deflector will not provide positive insurance that none of the fresh charge will be discharged with the hot gas and escape to the outer air through the muffler without ever being exploded

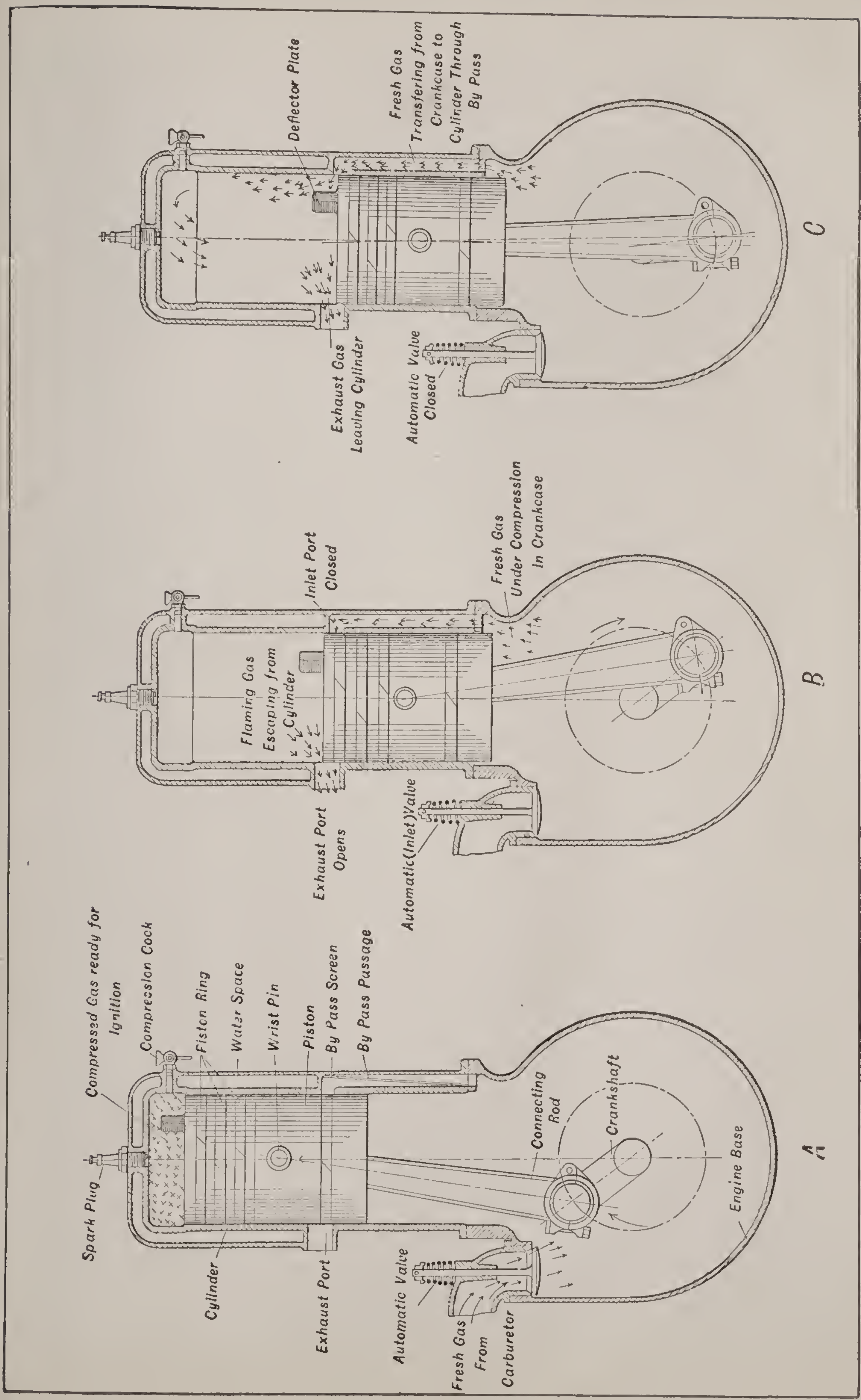


Fig. 45.—Diagrams Defining Action of Two-Stroke Motor.

at all. The efficiency of a two-cycle motor is considerably lower than that of a four-cycle, as while theoretical considerations would indicate that with twice the number of explosions one should double the power for a given cylinder volume, the actual increase over a four-cycle of the same size is but fifty per cent. Of course, the two-cycle engine has some real merits to offset the grave defects. Its extreme simplicity insures that nothing can go wrong with the engine itself because the piston, connecting rod and crankshaft are the sole moving parts. A two-cycle engine will continue to develop its rated power, and actually improves in power output as it continues in service. In a four-cycle engine, however, if the valve timing changes, as is very apt to occur when the valve-operating mechanism wears or gets out of adjustment, its efficiency is materially reduced. Barring accidents due to deliberate neglect, practically the only condition that can develop in the cylinder that will reduce the power output of a two-cycle engine is carbonization, and it is not a difficult matter to scrape off the carbon deposits from a simple cylinder with no valve chamber in the head, as employed in two-cycle engines. Of course, the bearings at the crank-case may wear to such a point that there will be a loss in crank-case compression, but this will not occur until the engine has been in service for a long period, and when bearing depreciation does materialize it is not a difficult proposition to refit the brasses, and restore the engine to its former efficiency. It is claimed that the two-cycle motor will not carbonize as quickly as the four-cycle because, while the latter is lubricated for the most part by haphazard hand pump supply, on most of the two-stroke engines lubrication is very easily accomplished by mixing the lubricating oil with the gasoline. The two-cycle construction is peculiarly well adapted for this system of lubrication, which would soon put a four-cycle engine out of commission because the fresh charge, which contains the oil emulsion, is first drawn into the crank-case where considerable of the oil will be deposited on the mechanical parts before the charge is directed into that portion of the cylinder above the piston. The two-cycle engine is not anywhere near as flexible as the four-cycle power plant, but it is capable of a high-power output at low speeds. Owing to the frequently recurring explosions an even pull or torque is obtained from a two-cycle motor, which promotes efficiency and

lessens wear of the transmission system, including speed-changing gear as well as final drive, and which also materially augments the life of the tire on the traction member.

Methods of Figuring Rated Horse-power.—To calculate the horse-power of any four-cycle motor, the following general formula may be used, this giving the output of a single cylinder, and must be multiplied by the number of cylinders for multiple cylinder engines:

$$\frac{P\ L\ A\ R}{33{,}000 \times 2} = \text{H.P.}$$

In which

P = Pounds per square inch.
L = Length of stroke in feet.
A = Piston area in inches.
R = The number of revolutions per minute.

The following can be used for either four-cycle or two-cycle motors, depending on the constant used as a divisor:

$$\frac{D^2 \times L \times n \times \text{M.E.P.} \times R.}{550{,}000} \text{ I.H.P. 4-cycle}$$

Constant for two-cycle engines, 275,000.

D^2 = Bore of cylinders in inches squared.
L = Stroke of piston in inches.
R = Revolutions per minute of crankshaft.
n = Number of cylinders.
M.E.P. = Mean effective pressure.

The formula below is a simple one for four-cycle engines, though the results can be multiplied by 1.50 to obtain power rating of average two-cycle engine of the same dimensions:

H.P. = PLD^2R with three decimal places pointed off.

In which

P = Mean effective pressure.
L = Stroke in inches.
D = Diameter in inches.
R = Number of cylinders.

The mean effective pressure can be assumed or taken from tables. A speed of 1,000 revolutions per minute is the only assumption made, and the formula takes into consideration pressure, bore and stroke,

and is the simplest form to which the writer has yet been able to reduce the horse-power fomula, still retaining all the essentials.

The pressure in any engine is assumed to be a mean effective pressure or average pressure throughout the stroke, and is written M.E.P. For gasoline engines of the usual four-cycle type, this pressure can be assumed at between 75 and 100 pounds, it, of course, varying with the general design. The actual mean effective pressure

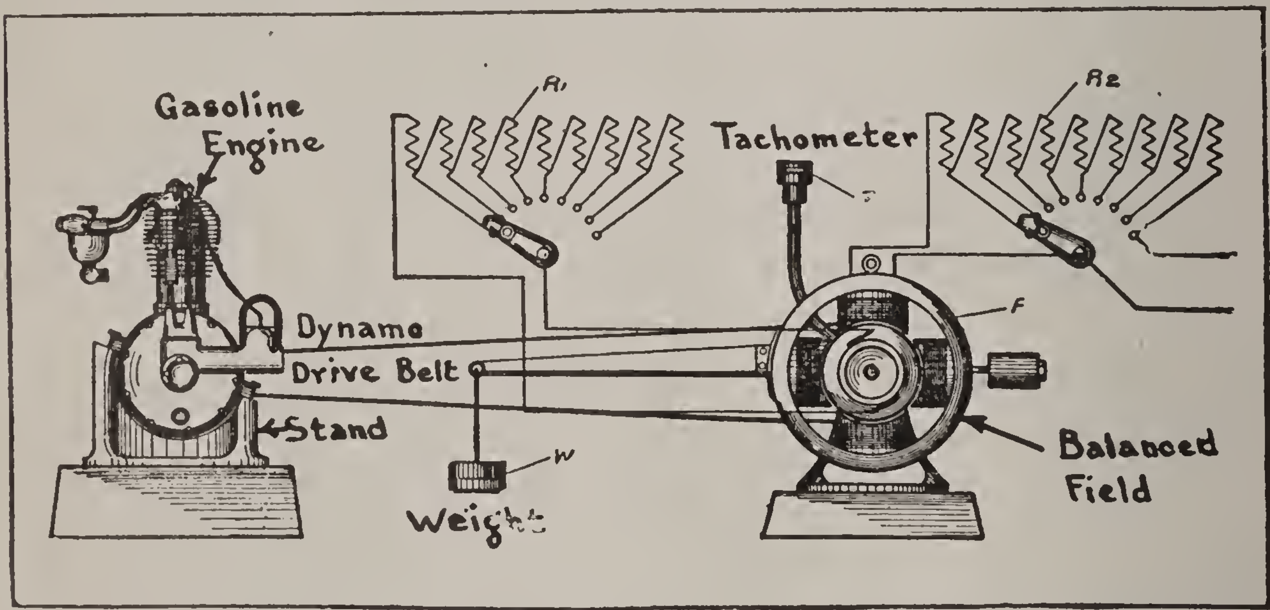


Fig. 46.—Method of Testing Power of Motorcycle Engine With Cradle Dynamometer.

of an engine which has already been built can be determined by the manograph, which records by means of a streak of light the outline of the indicator card, which, if desired, can be permanently retained by means of a photographic plate. It can also be determined at speeds under 500 revolutions per minute by diagrams produced by ordinary steam engine indicators, but these are not accurate when used with high-speed gasoline engines, the manograph being far superior.

Mean effective pressure increases as the compression, and decreases as the revolutions per minute augment. The thermal efficiency of a motor is the ratio between the work done and the thermal energy contained in the fuel consumed, and is between 15 to 30 per cent. The mechanical efficiency, by which is understood the ratio between the work actually done to the energy expended on the piston by the expanding gases, is approximately 85 per cent.

For easy comparison of one machine with another, and for facilitating handicapping at hill-climbs and race meets, the following formulæ have been given out by clubs and associations. For the sake of uniformity, let:

D^2 = Square of piston diameter in inches.
L = Stroke in inches.
R = Revolutions per minute.
N = Number of cylinders.

S.A.E. formula.......... $H.P. = \frac{D^2N}{2.5}$

Roberts formula......... $H.P. = \frac{D^2LNR}{1,800}$

Royal Auto Club......... $H.P. = \frac{(D + L)^2N}{9.92}$

TABLE OF HORSE-POWER FOR USUAL SIZES OF MOTORCYCLE MOTORS, BASED ON S. A. E. FORMULA.

Bore.		Horse-power.		
Inches.	M/M	1 Cylinder.	2 Cylinders.	4 Cylinders.
$2\frac{1}{2}$	64	$2\frac{1}{2}$	5	10
$2\frac{5}{8}$	68	$2\frac{3}{4}$	$5\frac{1}{2}$	11
$2\frac{3}{4}$	70	3	6	$12\frac{1}{10}$
$2\frac{7}{8}$	73	$3\frac{5}{16}$	$6\frac{5}{8}$	$13\frac{1}{4}$
3	76	$3\frac{3}{5}$	$7\frac{1}{5}$	$14\frac{2}{5}$
$3\frac{1}{8}$	79	$3\frac{15}{16}$	$7\frac{13}{16}$	$15\frac{5}{8}$
$3\frac{1}{4}$	83	$4\frac{1}{4}$	$8\frac{1}{2}$	....
$3\frac{3}{8}$	85	$4\frac{9}{16}$	$9\frac{1}{8}$	....
$3\frac{1}{2}$	89	$4\frac{9}{10}$	$9\frac{4}{5}$	....
$3\frac{5}{8}$	92	$5\frac{1}{4}$	$10\frac{1}{2}$	....
$3\frac{3}{4}$	95	$5\frac{5}{8}$	$11\frac{1}{4}$	....
$3\frac{7}{8}$	99	6	12	....

To simplify reading of the above, the horse-power figures are approximate, but correct within one-sixteenth.

How Actual Horse-Power is Tested.—While it is possible to arrive at some estimate during the preliminary designing or construction of a motorcycle power plant of the amount of power that can be expected, the only true indication of actual engine capacity is some form of dynamometer or brake test. A typical method of testing is illustrated at Fig. 46 and the general arrangement of parts can be readily understood by referring to the diagram. The apparatus used for this test is known as a "cradle-dynamometer" and power is measured by an electro-magnetic pull, the value of which increases as the engine capacity augments. The motor drives the armature of what is really an electric generator by a belt, and an electric current is produced which is dissipated or absorbed by the resistance R1. This current sets up a magnetic attraction which tends to pull the field around with it. This field ring is not only very carefully balanced but is supported by ball bearings in the pedestals which permit it to oscillate with but slight magnetic pull. The amount of magnetic attraction may be measured by the weight W carried at the end of the long lever attached to the oscillating field. The pull depends upon the amount of current flowing through the field, and this is usually supplied from an independent source and is controlled by the rheostat R2. In calculating the power developed, it is necessary to know the number of revolutions the armature is making, so this is determined by the revolution counter or tachometer T which is driven from the armature shaft by suitable gearing and a flexible shaft.

In making a test, a number of resistance coils in the rheostat R1 are put in circuit for absorbing the armature output, and enough electric current from some extraneous source is allowed to flow through the field by means of the rheostat R2 to hold the motor down to the required speed. Weights are placed on the arm at W until the field ring balances. The number of revolutions as indicated by the tachometer is noted and the horse-power obtained under these conditions may be readily computed. If it is desired to test the horse-power at lower or higher speeds, the weights are removed and the amount of current flowing through the field is altered to obtain

the desired speed. If the current is increased the speed becomes less, while decreasing the current will allow the motor to run faster. When the proper number of revolutions are obtained, the weights are changed until the field ring again balances. The horse-power is very easily found by a simple formula which can be expressed as follows if one assumes that the distance from where the weight is supported to the center of the armature shaft is one foot:

$$\text{H.P.} = \frac{\text{Weight} \times \text{R.P.M.} \times 2 \times 3.1416}{33{,}000}$$

For example, if the motor pulls 29 pounds at 2,400 revolutions per minute, we would have, substituting known values in the above formula:

$$\frac{29 \times 2{,}400 \times 2 \times 3.1416}{33{,}000} = 13.25 \text{ H.P.}$$

If the field current is strengthened so that the motor is slowed down to 1,500 revolutions per minute and the torque is indicated as 36 pounds, we have:

$$\frac{36 \times 1{,}500 \times 2 \times 3.1416}{33{,}000} = 10.\ 28 \text{ H.P.}$$

The actual horse-power of an engine may be determined by other forms of dynamometers, of which the Prony brake is a widely used form. This differs from the electric devices described, as the power delivery is obtained by a friction brake that, in its simplest form, may consist of a rope passed around a fly-wheel or pulley attached to the motor shaft or driven by it and having its free ends attached to spring balances or one attached to a fixed point while the other is weighted. The usual form of Prony brake consists of a band of leather or steel to which a number of hardwood blocks are fastened, and the whole is bent around the fly-wheel of the engine to be tested to form a brake band, which may be made to bear against the fly-wheel with any degree of pressure desired by the operator. A lever is attached to one side of the brake hand, and the tendency of the revolving fly-wheel to carry the lever around with it when the band is tightened, is resisted by weights or spring balances. The method of determining

the power with the mechanical brake is just the same as that followed when the electric cradle dynamometer method is employed.

Another simple and effective method of determining the horse-power is to have the engine run a generator of electricity and absorb the current delivered by any suitable resistance such as banks of incandescent lamps. The current output from the generator may be measured, and for every 746 watts of current obtained, the engine is delivering about 1.10 horse-power. While 746 watts is the electrical equivalent of a horse-power, there is a certain loss in energy in converting the mechanical power into electric current, and this must be considered in determining the engine power. Still another method of obtaining the actual horse-power of a gasoline engine is by driving a large air fan which has movable vanes or plates attached to the arms so that these may be placed at any point on the length of the arm. As it takes a certain amount of power to overcome air resistance, if the area of the plates is known, one can determine the amount of power delivered by the engine by considering the distance the blades travel in a given time.

Relation of Torque to Horse-Power and Its Meaning.—In considering the power capacity of various types of prime movers, "torque" is a technical term that receives considerable application, and like most of the simple mechanical expressions, it does not mean much to the average reader of semi-technical or mechanical works. As it is a very simple way of expressing power delivered to or by a rotating member, such as an engine crankshaft, pulley, sprocket or wheel, it seems desirable that a more general understanding of this term should exist. The writer has used this expression previously, and as it will be employed in a number of the chapters to follow, in exposition of power generation and transmission systems, the appended brief explanation may serve to promote a proper understanding of its meaning.

It is generally known that power is expended in doing work, and that as the amount of work or resistance is increased, the amount of power or energy required augments proportionately. The power delivered by an engine crankshaft can be expressed very well as "torque" which generally is considered in pounds-inches or pounds-feet, or simply as a certain pull or push having a definite value in pounds.

The relation between torque and horse-power is simply that the former is produced by or can produce the latter. The amount of torque is directly proportional to the power producing it, and it increases as the power augments, if the rotative speed remains constant.

For example, we desire to find the useful driving force or power delivered by a gasoline engine of certain proportions. If the engine was used in motorcycle propulsion, it would be desirable to know the amount of pull that would be present at the pitch line of the driving sprocket, in order to ascertain if the engine could overcome the resistance of traction wheel movement. This pull would be a torque of so many pounds value depending upon the speed and power of the engine and the distance between the sprocket pitch line and a point at crankshaft center. In ascertaining the value of the turning effort or torque, it is desirable to find the amount present at one inch radius from shaft center first, then the actual pull may be readily determined by dividing the torque in inch-pounds by the distance in inches from the crankshaft center to the point where the power is exerted.

The following simple example will clearly define the practical application of the formula previously used to this case. The formula expressed as a rule is: Torque is equal to the product of the horse-power multiplied by 63,024, divided by the revolutions per minute of the shaft. This rule is almost universally employed in determining the value of the pull available from a given power at a definite point of one inch from shaft center. Assuming that the engine in question was capable of delivering 10 horse-power to its crankshaft, at a speed of 2,000 revolutions per minute, and that we wish to find the pull available at the driving face of a 6-inch diameter, flat belt pulley, attached to the engine crankshaft, we can substitute known values and have the following expression:

$$\frac{10 \times 63{,}024}{2{,}000} = \frac{630{,}240}{2{,}000} \text{ or 315 inch-pounds.}$$

Dividing this value by the radius of the pulley, or 3 inches, gives us a pull equivalent to 105 pounds at the pulley surface. If this could be transmitted without loss directly to the 18 inches diameter driving pulley on the rear wheel, we would have a pull of 105 pounds on the surface of that member at 9 inches radius from traction wheel

center. Owing to the difference in size between the pulleys, the driven member would turn at but one-third the speed of the driving member on the engine shaft, or 666.66 revolutions per minute. Even though the wheel turns slower, the torque, one inch from the traction wheel center, would be equivalent to 10 horse-power, as while it would be 945 inch-pounds, the speed of the rear wheel is but one-third that of the engine shaft, and therefore the torque should be three times as much. If the amount of power remains constant, the torque or pull increases as the speed is reduced, and diminishes as the speed of rotation is augmented. Torque or pull is always greatest near shaft center, as for example, at one-half inch radius it is twice as great as at one-inch radius, all other conditions remaining equal. It is usually based on one inch radius to facilitate calculation. An engine capable of exerting a torque or pull of 315 inch-pounds would only exert 26.20 pounds pull at 12 inches radius under the same speed and power conditions. The torque of large engines is measured in foot-pounds in order to simplify figuring, while that of smaller capacity power plants is more often expressed in inch-pounds.

When actual horse-power tests are made, there is a point in every horse-power diagram where the torque and horse-power curve lines intersect, and an engine is not exerting its greatest torque at its highest rotative speed. It will be noted that the horse-power curve in the diagrams at Fig. 47 attains its maximum value at a certain point, and from there it drops as the speed increases. This falling off in power is on account of the higher mechanical losses in the power plant at high speeds due to the increased friction of the parts and also thermal losses because of difficulties in scavenging or clearing out the cylinder properly and taking in a full charge of fresh gas. As one would expect, the torque is greatest at low speeds, and gradually becomes less as the speeds of rotation increase. The relation of torque and horse-power lines to each other when plotted on charts is clearly shown in the diagrams at Fig. 47. In the upper one, the test of a single cylinder engine rated at 5 horse-power is shown, while in the lower one the results obtained by testing a 9 horse-power nominal rating twin-cylinder engine are plotted.

Such diagrams are not difficult to read, and they are especially valuable in presenting a large volume of information in a small space.

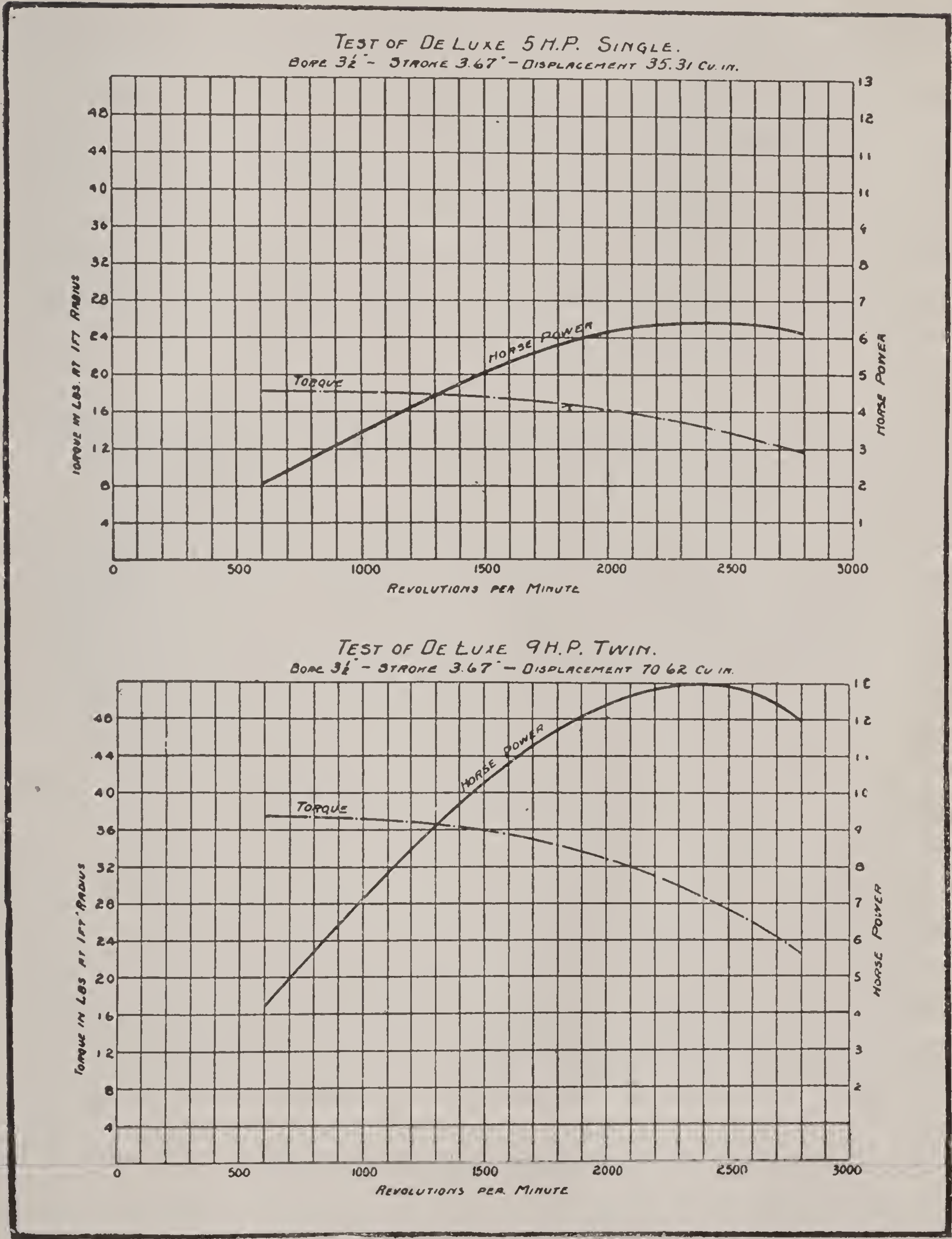


Fig. 47.—Curves Showing Horse Power of Gasoline Motors at Various Speeds of Crankshaft Rotation.

To read these diagrams, it is merely necessary to trace a vertical line denoting the speed in revolutions per minute desired to the point where it intersects the horse-power curve, and then following out the

horizontal line to the right of the chart, where the horse-power delivered at that speed will be clearly indicated. The same procedure is followed in reading the torque, only that the horizontal line is followed to the left of the diagram where the torque in pounds at one foot radius is outlined. For example, considering the upper chart, it will be apparent that if we follow the vertical line indicating 1,300 revolutions per minute upward, we will find that it intersects both the torque and horse-power curves. Following an imaginary horizontal line from this point on the diagram to the right, we find that the engine in question is developing approximately 4.50 horse-power while the torque is about 18 pounds. It will be observed that the power plant rated at 5 horse-power will develop 6.33 horse-power at 2,400 revolutions per minute.

Another diagram that gives some interesting data pertaining to the relation of motorcycle speed in miles per hour and the engine power developed is presented at Fig. 48. It will be observed that the maximum engine power represented by the highest point in the curve is obtained at a vehicle speed of approximately 47.5 miles per hour, and that from this point to 65 miles per hour the power curve drops appreciably. At 47.5 miles, the engine is delivering 13.9 horse-power, whereas at a rear wheel speed corresponding to 65 miles per hour the engine is developing but 9.3 horse-power. The horse-power obtained by this test is different than that secured by trial of the engine alone, and the object was not to ascertain the brake horse-power of the engine but the actual power available at the rear wheel for traction, which, on account of mechanical losses in the power transmission system, would be fully 20 per cent less than the amount of power that would be shown by the engine on a brake or dynamometer test where the power of the engine crankshaft would be measured instead of that proportion of it delivered at the rear wheel.

A simple rule for finding the torque at one-inch radius from center, exerted by a shaft rotated with a given amount of power that can be easily memorized, if one assumes a speed of rotation of 1,000 revolutions per minute, is: Multiply the horse-power by 63, which will give the pull in inch-pounds, and then divide this product by the distance in inches from shaft center to the point of power application, and the result is the torque or pull available at that point directly in pounds.

Reason for Cooling Engine.—It is apparent that power is produced in an internal-combustion engine by a series of explosions in the cylinder. As the temperature of the explosion is over 2,000 deg. Fahr. in some cases, the rapid combustion and continued series of explosions would soon heat up the metal parts of the combustion chamber to such a point that they would show color unless cooling means were provided. Under these conditions, it would be impossible to lubricate the cylinder, because even the best quality of lubricating oil would be burnt. The piston would expand sufficiently to seize in

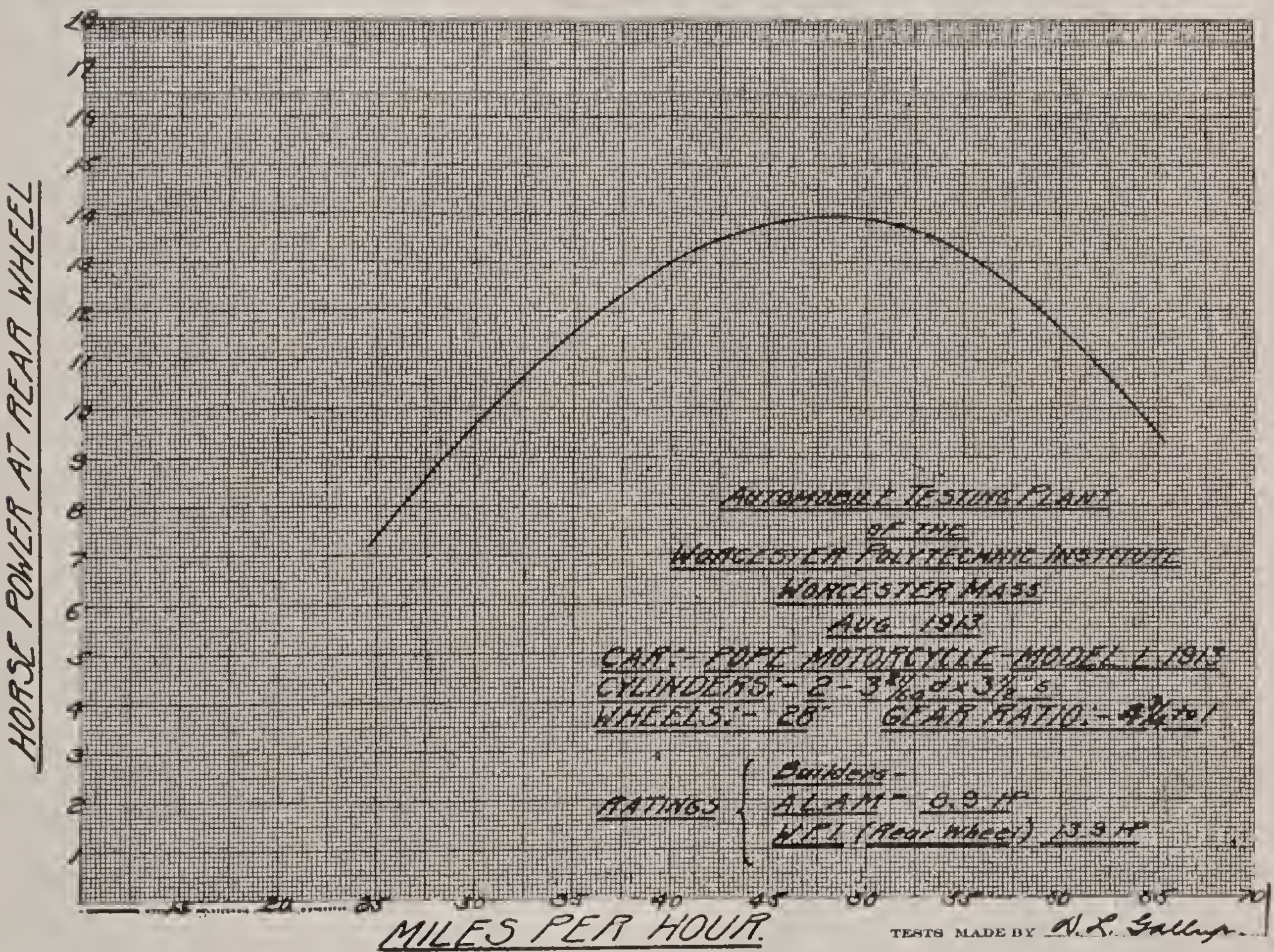


Fig. 48.—Chart Showing Horse Power at Rear Wheel of Motorcycle at Various Speeds.

the cylinder and the valves would warp so that they could no longer hold compression. Premature ignition of the charge would probably take place long before the engine was put out of commission by the distortion of the parts.

The fact that the ratio of engine efficiency is dependent upon the amount of useful work delivered by the heat generated from the ex-

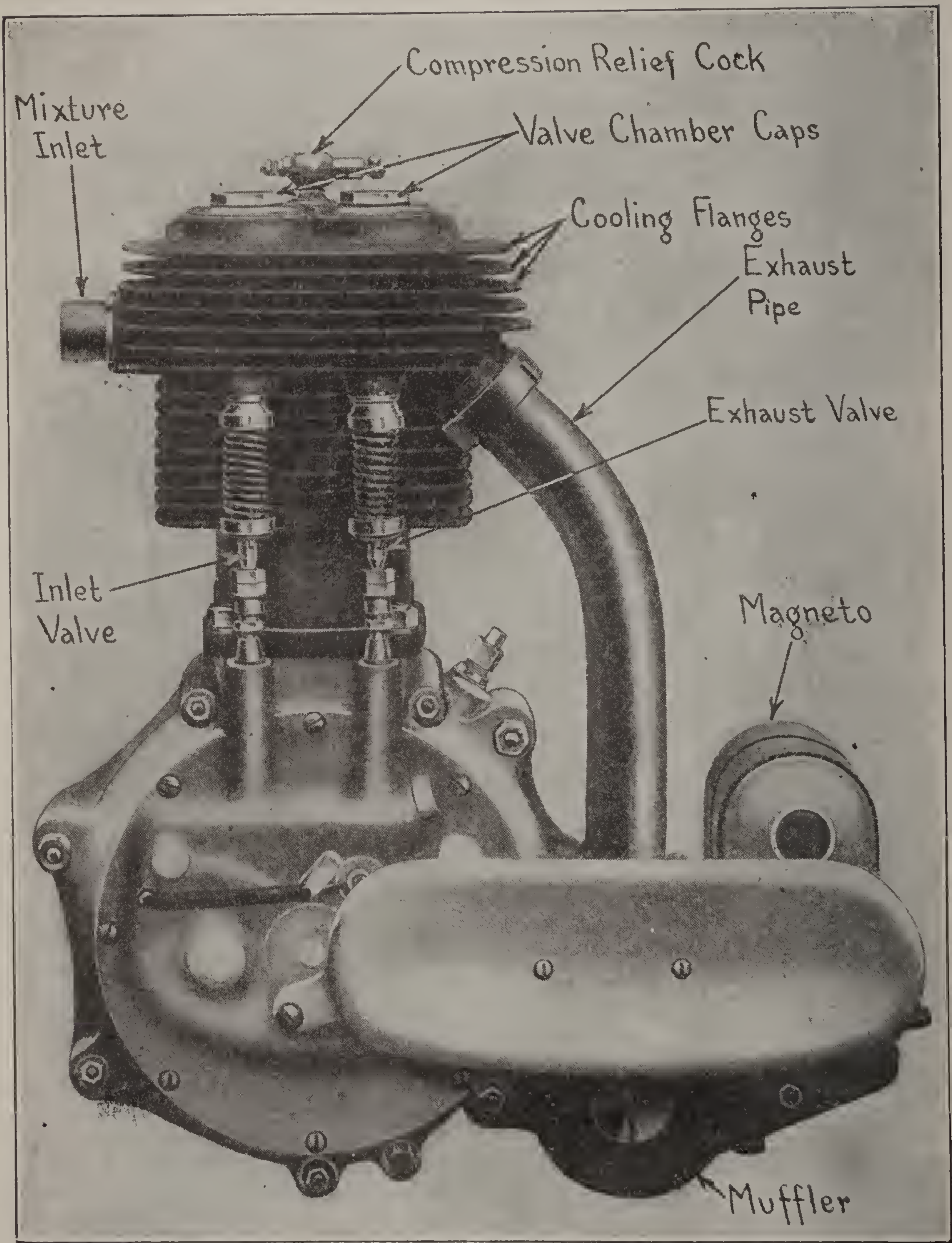


Fig. 49.—Typical Single Cylinder Motorcycle Power Plant, Showing Arrangement of Cooling Flanges to Increase Radiating Surface of the Cylinder.

plosion makes it important that the cylinders be cooled to a point where the cylinder will not be robbed of too much heat. The losses through the water jacket of the average water-cooled automobile power plant are over 50 per cent of the total fuel efficiency. While it is very important that the engine should not get too hot, it is equally desirable that it is not cooled too much. The object of cylinder cooling is, therefore, to keep the heat of the cylinder metal below the danger point but at the same time keep the engine hot enough to obtain maximum power from the gas burnt.

Air or Water Cooling.—The method of abstracting the heat from the cylinder generally employed in the small motors used in motorcycle propulsion is by means of direct air cooling, though on the larger motors, sometimes used in cycle car and light automobile service, the heat is absorbed by water circulated around the cylinders through a suitable jacket which keeps it confined against the heated portions. In an air-cooled engine, the application of the air to the cylinders is direct, and there is no intermediate transfer of heat from the cylinder wall to the radiating surfaces by means of water. Any water-cooling system must, of necessity, be indirect, as after the water is heated it must pass through a radiator where it is subjected to the cooling influence of air currents to reduce its temperature, and make it available for further use. In a motor which employs a water-cooling system, there is a certain loss of heat to the water jacket which is called "Jacket Loss," and the amount of heat wasted in this manner depends upon the difference in temperature between the heat of the explosion and the heat of the cylinder wall. As water loses its cooling efficiency when it boils, the temperature of the water jackets, and consequently the wall of the water-cooled cylinder, must be maintained at a point below 212 deg. Fahr. which is the boiling point of water. The temperature of the cylinder wall of an air-cooled motor may be readily and safely maintained at a temperature nearly 150 degrees higher. This would indicate that, with a reduced heat loss, an air-cooled motor would be more efficient than a water-cooled form. Then, of course, the features of simplicity that are so necessary in motorcycle design cannot be readily obtained if the water-cooling system is employed because in its simplest form it requires a radiator to cool the water, and suitable piping to conduct the water from the

engine cylinder water jacket to the point where the heat is radiated into the air. As an air-cooled engine can be made considerably lighter than a water-cooled form, and as the direct system of cooling has demonstrated that it is thoroughly practical for the small engines used in motorcycle work, it does not seem necessary to provide motorcycle motors with water jackets. All of the American motorcycles use the air-cooling method, though several foreign machines have water-cooling systems.

Efficiency of Air-Cooled Motors.—The air-cooled motor is more efficient than the water-cooled forms, because in any internal combustion engine it is the heat energy of the fuel that is converted into useful work. This transformation is brought about by the rapid combustion or burning of the fuel which is often called "an explosion." The rapidly burning gases develop high pressures which produce power, as we have seen, by acting on the piston and the reciprocating parts. The temperature and pressure of the explosion both fall very rapidly, on account of the rapid escape or transfer of heat through the walls of the cylinder and the piston head. A certain amount of heat loss is a necessary evil that cannot be avoided in any internal combustion engine, and as previously stated, efficient lubrication cannot be obtained if the cylinders get much hotter than 400 deg. Fahr. A cylinder may be allowed to heat up to 350 deg. Fahr. and still be on the safe side as far as effective lubrication is concerned. In comparing the efficiency of air and water cooled motors, a good method of doing this is to base the values on the amount of mileage possible on a given fuel consumption. An air-cooled engine will use a maximum of 0.80 of a pound of gasoline for each brake horse-power hour at half load, and 0.60 of a pound of gasoline for each brake horse-power hour developed at full load. The average water-jacketed automobile engine will use from 1 to 1.50 pounds of fuel at half load, and from 0.90 to 1.20 pounds per brake horse-power hour at full load. From the foregoing, it will be apparent that the air-cooling system is more efficient and economical than the water-cooling methods, and in view of its simplicity it is not difficult to understand why it is almost universally used in motorcycle power plants of American design.

Air-Cooling Methods.—Air cooling may be obtained by two methods: either simple radiation, or combined radiation and con-

vection. The former system is used only on motors of a stationary type that are not provided with a cooling fan. The most widely used system is a combination of radiation and convection. Radiation simply means that the heated air rises from the hot cylinder because it is lighter than the cooler air which takes its place. Convection means cooling by air in motion, and, obviously, wherever convection is used there must, of necessity, be included the radiation principle. The method generally used on motorcycles where the power plant is exposed to the air, and where the cylinder is swept by air drafts or currents created by the rapid travel of the machine, is to augment the normal available radiating surface of the plain cylinder by providing cooling flanges as indicated at Figs. 49 and 50.

These flanges not only surround the entire cylinder exterior but also cover the valve chamber and the cylinder head. By the use of these members, the area of radiating surface is largely increased, and while air has considerably less capacity for absorbing heat than water, the surface from which the heat is radiated may be increased to such a point by judiciously placed flanges so the heat will be dissipated fast enough to keep the cylinder from overheating. The cooling flanges may be of the same diameter the entire length of the cylinder, as shown at Fig. 49, or they may become less in diameter as the cylinder temperature decreases, as shown at Fig. 50. They are widest at the combustion chamber, and taper down in diameter to but little more than that of the cylinder at the bottom of that member. On some types of flange-cooled engines, the designers drill holes through the flanges as indicated at Fig. 51, and while these materially reduce the effective radiating surface it is claimed that there is more opportunity for the cooling-air current to pass around and between the flanges, and thus superior cooling is obtained. The air-cooling flanges on most motorcycle power plants are placed horizontally, or at right angles to the cylinder center line, though in some forms, where the cylinder is inclined, the flanges are disposed at an angle to the cylinder wall so that they will be approximately horizontal when the power plant is in position. On some forms of double cylinder opposed engines, the flanges run the length of the cylinder, in order to promote free circulation of air. Where air-cooled motors are protected by a hood or bonnet, as in cyclecars and light automobiles, it is customary

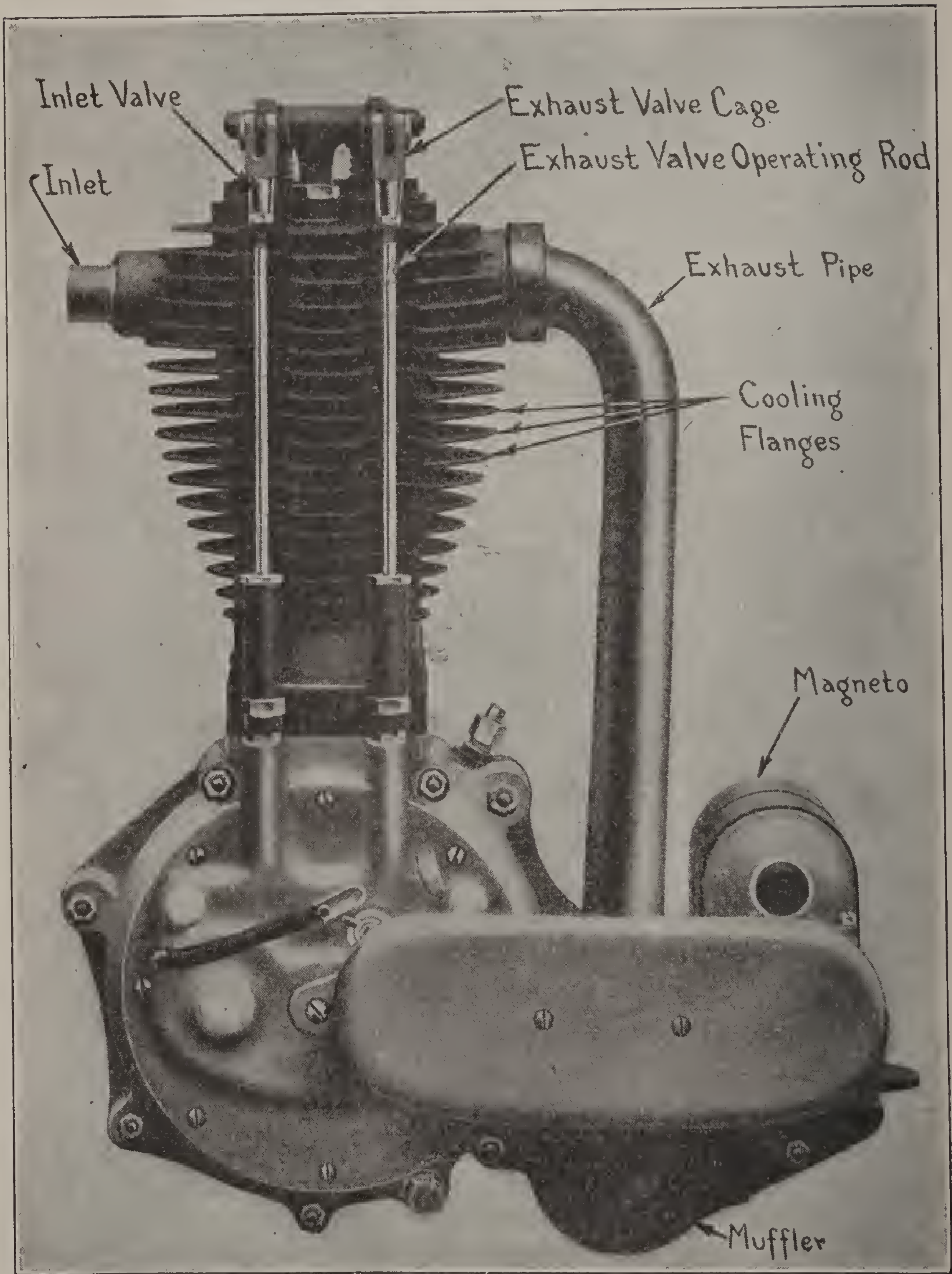


Fig. 50.—The Precision Overhead Valve Air-Cooled Motor Having Cooling Flanges of Graduated Diameters.

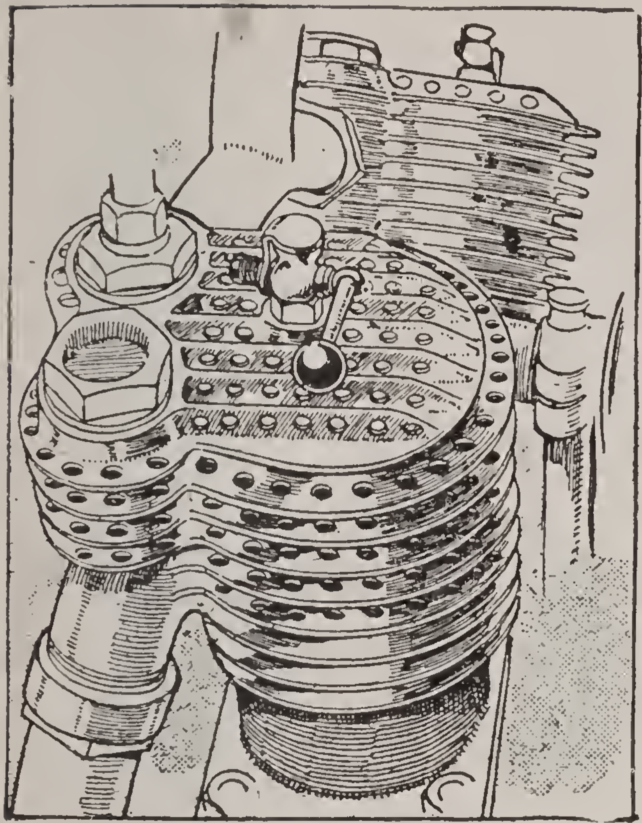


Fig. 51.—Showing Method of Perforating Flanges to Facilitate Air-Cooling.

to provide a cooling fan driven from the engine crankshaft to keep a constant draft of air in motion around the engine cylinders. In some automobile power plants the cylinders have been encased in sheet metal jackets, and air currents from a blower are made to circulate through these jackets and around the cylinders, but this is not necessary on motorcycles. Copper-plating the cylinders increases the rate of heat transfer to the air. Radiation may also be augmented by painting the cylinders with a dull black stove polish.

Water-Cooling Methods.—When a liquid is employed for cooling it is circulated through jackets which surround the cylinder castings, and when the excess heat is absorbed, the hot liquid is led to a cooler where the heat is abstracted from it by means of air currents. The cooled liquid is then taken from the cooler and again circulated around the cylinders of the motor. The view of a typical one-cylinder motor at Fig. 53 shows the arrangement provided for water cooling by radiators attached to the engine cylinder.

Two methods of keeping the cooling liquid in motion are used. The simplest system is to utilize a natural principle that a hot liquid being lighter than a cold one will tend to rise to the top of the cylinder when it becomes heated, while cool water takes its place at the bottom of the water jacket. The more complicated system is to use a positive circulating pump of some form which is driven by the engine to keep the liquid in circulation.

Some eminent motorcycle designers contend that the rapid circulation of liquid obtained by means of a pump may cool the cylinders too much and the temperature of the engine may be reduced to a point where its efficiency will be somewhat lower than if the engine

were allowed to run hotter. For this reason, some foreign engineers use the natural method of water circulation. The cooling liquid is applied to the cylinder jackets below the boiling point and the water issues from the top of the jacket after it has absorbed enough heat to raise it just about to the boiling point. The simplicity of the thermo-syphon system of cooling makes it specially adapted to motorcycles and other light vehicles. With this system of cooling, it is necessary to use more liquid than with pump-circulated systems, and the water jackets of the cylinders, as well as the water spaces in the radiator and the water inlet and discharge manifolds, should have greater capacity and be free from sharp corners that might impede the flow of liquid.

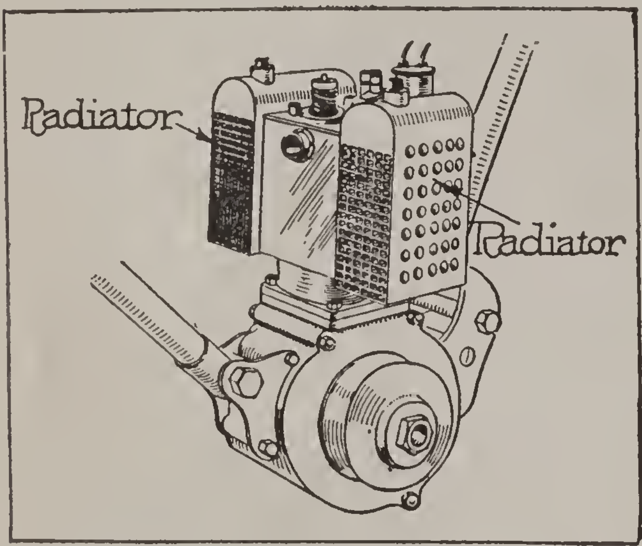


Fig. 52.—View of Green-Precision Motor With Radiators Attached to the Sides of the Water Jacket.

A system of cooling in which a pump is depended on to promote circulation of water is sometimes employed in cyclecar practice. The radiator is generally carried at the front end of the frame, and serves as a combined water tank and cooler in most cases. It is usually composed of upper and lower water tanks, joined together by a series of pipes, which may be round and provided with a number of corrugated flanges to radiate the heat, or which may be flat in order to have the water pass through in thin sheets and cool more easily. The cold water which settles at the bottom of the cooler is drawn from the lower part of the radiator by a gear-driven pump and is forced through a manifold to the water jackets surrounding the exhaust valve chamber of the cylinder. As the water becomes heated, it passes out of the top of the water jacket into the upper portion of the radiator, but as a general rule the rate of circulation is dependent upon the power and speed of the pump rather than the degree of temperature of the water. On account of the more rapid flow of liquid, the radiator and piping may be of less capacity than when the simple thermo-syphon is employed.

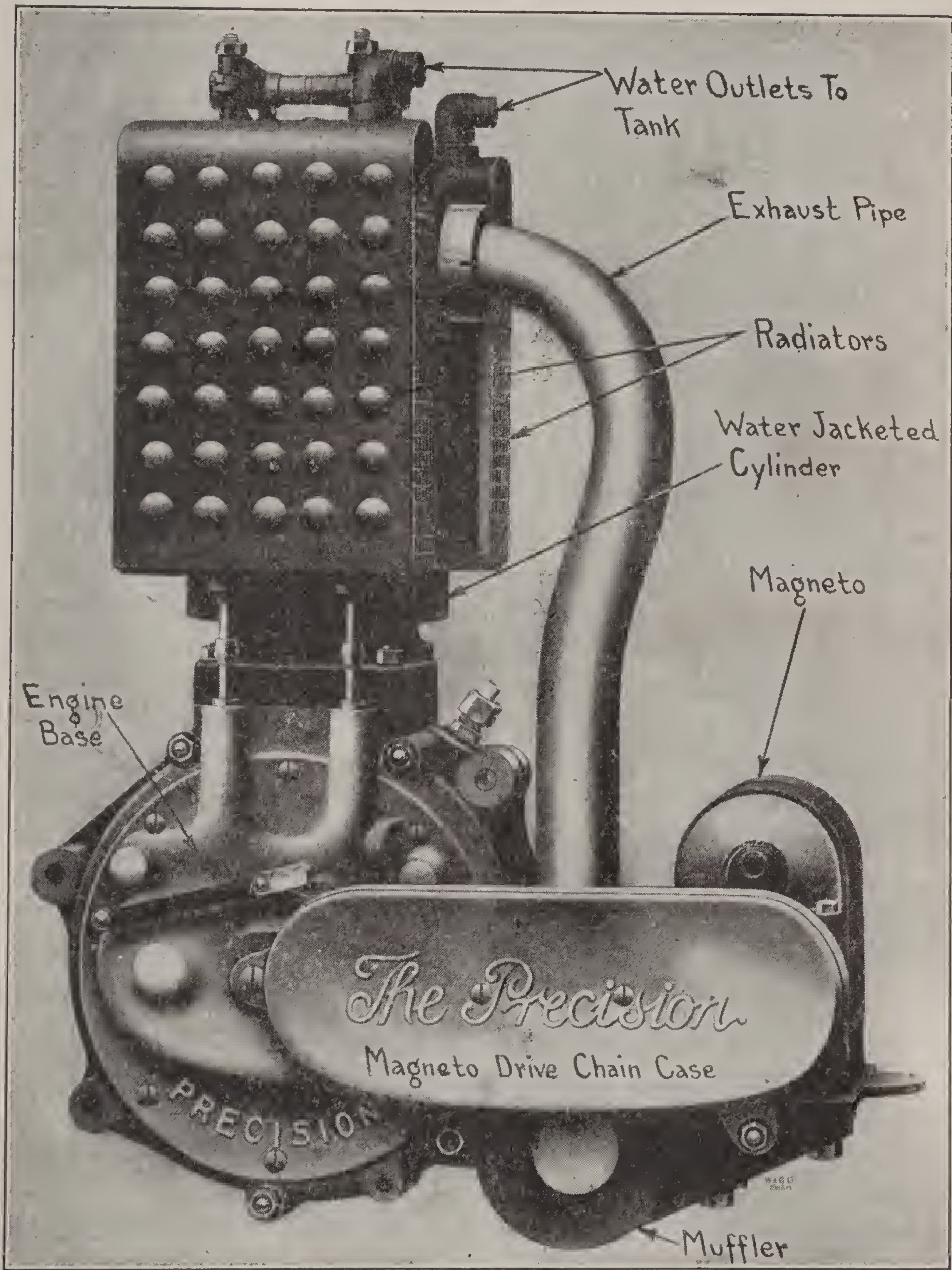


Fig. 53.—Complete Water-Cooled Power Plant With Radiators Integral.

Some typical water-cooled motors that have been designed for motorcycle use abroad are shown at Figs. 52 to 54 inclusive. The engine shown at Fig. 52 in place on the motorcycle frame is the same as that depicted at Fig. 53, and it will be observed that the radiators which serve to cool the water are attached directly to the sides of the water jacket. There is ample opportunity for the air currents to pass through the radiators, and it is possible to carry a reserve supply of water in a tank attached to the top frame bar which may be used as an auxiliary source of supply by connecting it to the water outlets at the top of the radiator that are clearly depicted at Fig. 53. On very small engines, it will be unnecessary to provide any water container, as the radiators themselves may hold enough water to secure adequate cooling.

Both of the engines depicted at Fig. 54 are of the two-cycle form and are shown in the position they occupy in the motorcycle frame to which they are fitted. That at A is the Rex motor, and it will be observed that the radiator is placed at the front end of the machine just back of the steering head and follows the diagonal tube extending from the steering head to the motor crank-case. The bottom of the radiator is connected directly to the bottom of the water jacket, and the heated water from the top of the cylinder passes through suitable pipes to the top of the radiator. The cooling system depicted at B is that of the Scott motorcycle, and the disposition of the radiator and arrangement of water piping is practically the same as in the example previously considered.

The engine depicted at Fig. 53 is a four-cycle form while those outlined at Fig. 54 are two-cycle engines which are said to be more difficult to cool successfully by air than the conventional form of four-stroke engine in which one entire stroke of the piston is devoted to clearing out the burnt gases from the cylinder while another full stroke is utilized in drawing in a cool charge of fresh gas. The Shickel engine, an American two-cycle form shown at Fig. 58, is cooled successfully by air, and in view of the fact that air cooling has been applied successfully to motor truck engines having 4.50-inch bore and operating on the two-cycle principle, it is apparent that it should be more successful and practical on the smaller two-stroke engines employed as motorcycle power plants.

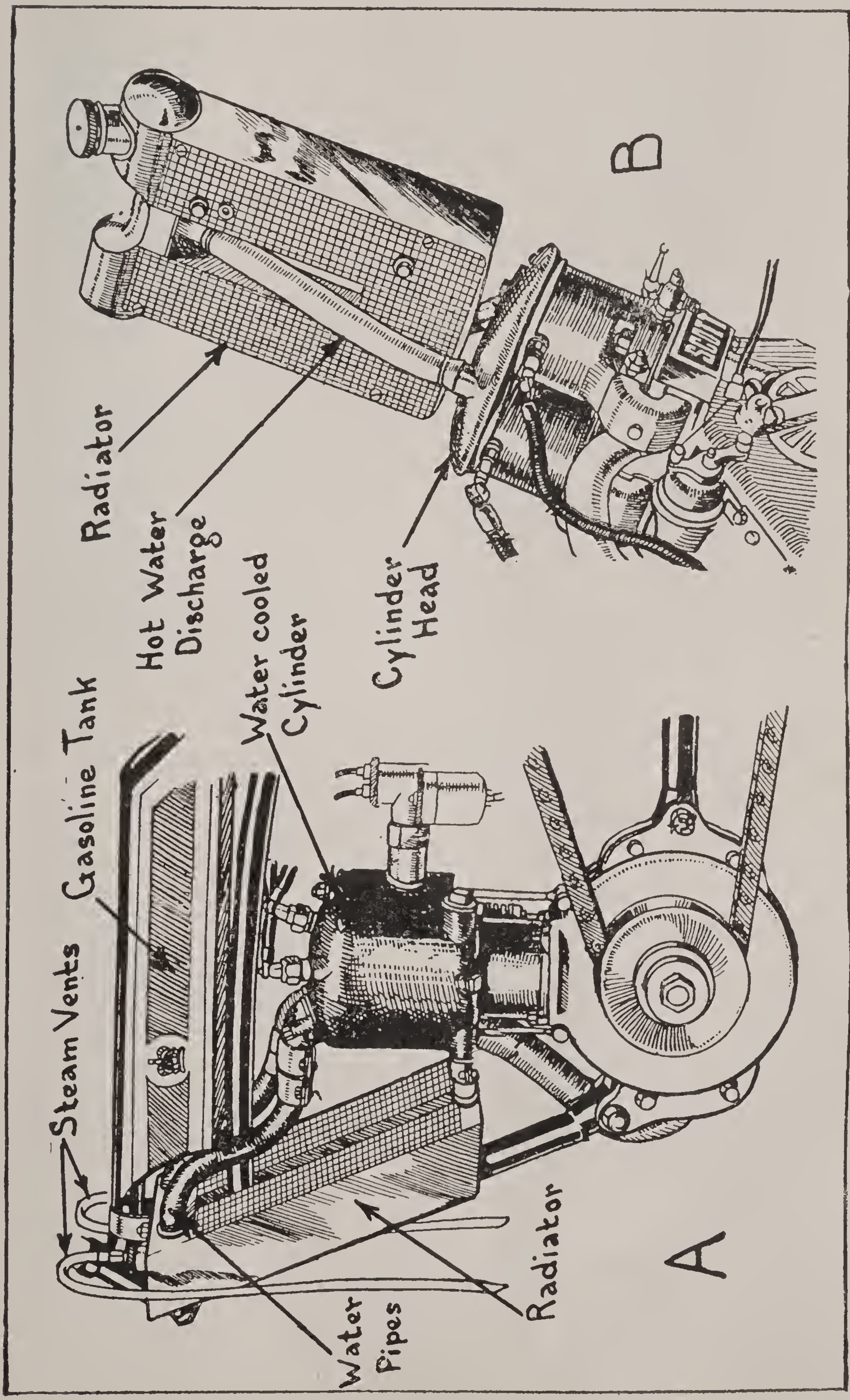


Fig. 54.—Water-Cooled Motorcycle Power Plants of English Design, Showing Arrangement of Radiators and Water Connections.

Features of One-Cylinder Motors.—The single-cylinder engine offers a main advantage of extreme simplicity. This is of considerable importance in the lighter motorcycles that are to be operated by inexperienced riders. Among some of the disadvantages that may be cited against the single-cylinder power plant are greater weight in proportion to power developed, lack of even power application because only one stroke out of four made by the piston is effective. A one-cylinder engine lacks the even turning moment and steady running qualities that a multiple-cylinder power plant possesses. If run faster

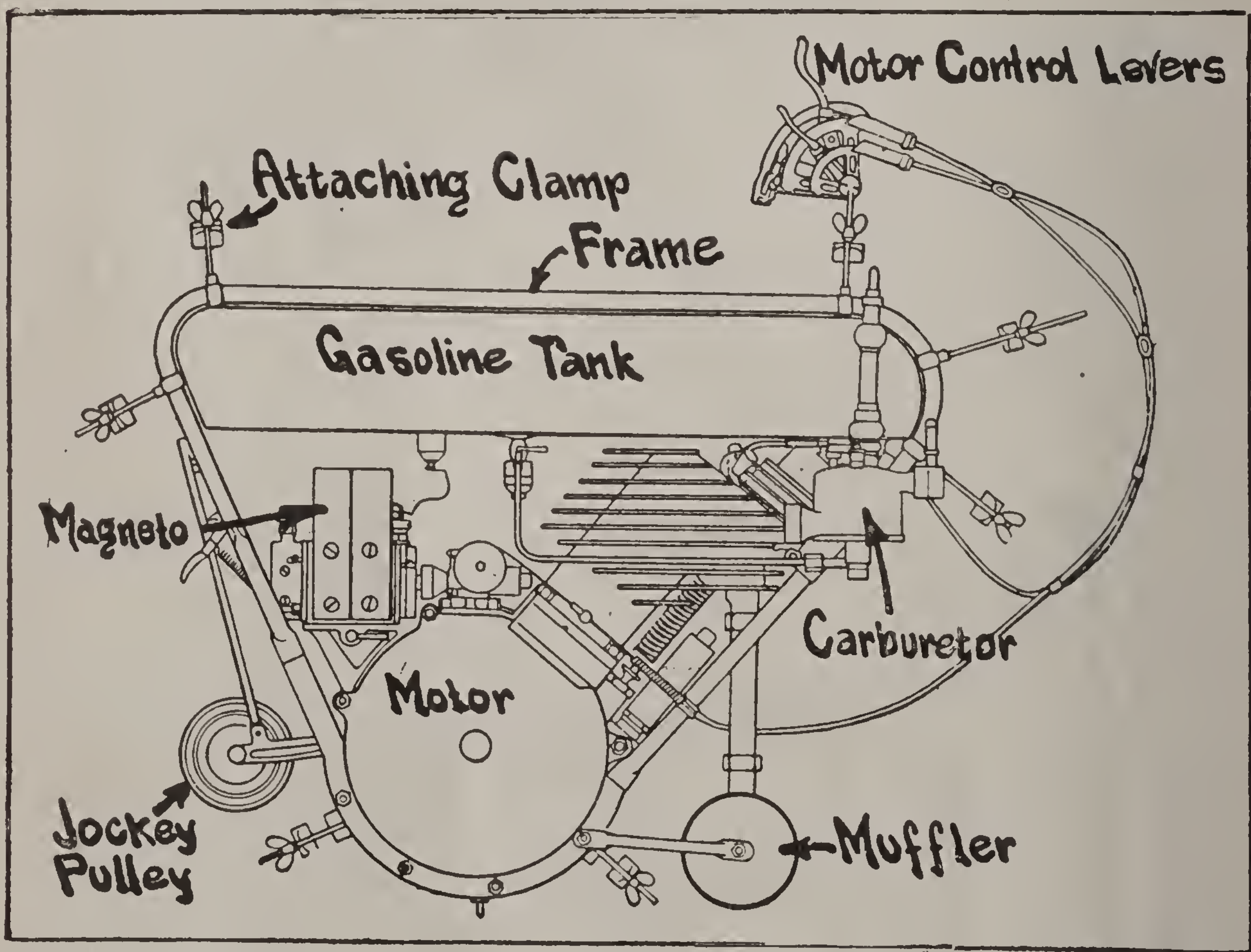


Fig. 55.—Typical Complete Power Plant Unit Adapted for Attachment in Standard Diamond Frame Bicycle.

or slower than the critical speed for which it was designed, there will be considerable vibration. Despite these faults, the single-cylinder engine is very practical in applications to light and medium-weight machines, and ample power may be obtained to cope with any condition ordinarily met with in road service. Typical one-cylinder engines are illustrated at Figs. 55 to 57, inclusive.

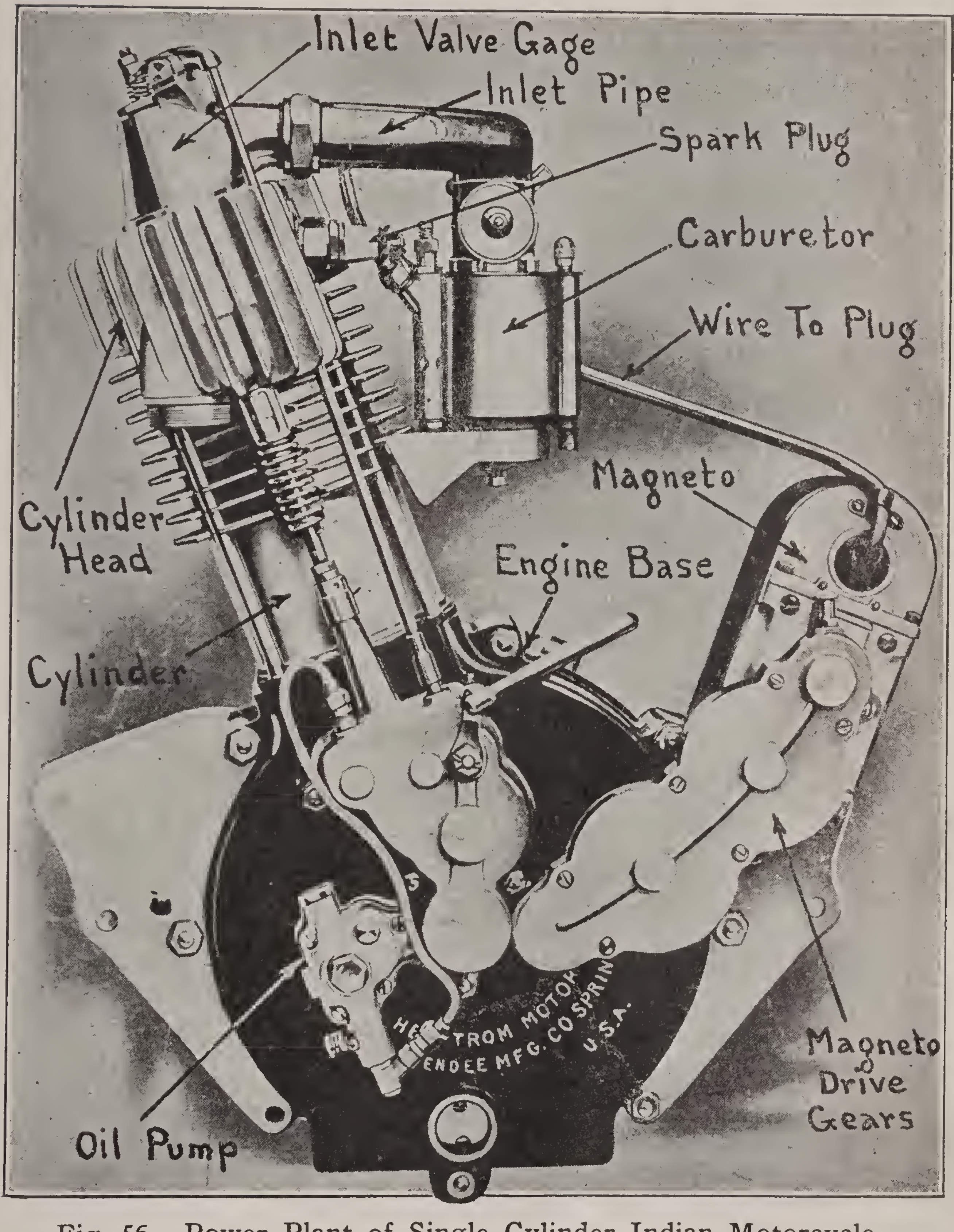


Fig. 56.—Power Plant of Single Cylinder Indian Motorcycle.

If of the two-cycle type, one will obtain the same even torque and steady application of power with one cylinder as provided by a two-cylinder opposed four-cycle engine, and steadier running than provided by most V-twins, though one must sacrifice some of the flexi-

bility and quick get-away of the four-cycle power plant to obtain the advantages of the simpler two-stroke motor. The Schickel two-cycle motor construction is shown at Fig. 58.

Advantages of Multiple-Cylinder Motors.—Power is obtained in the multiple-cylinder motor by using a number of cylinders instead of one large member. The cylinders are arranged in such a way that any multiple-cylinder motor may be considered as a number of single-

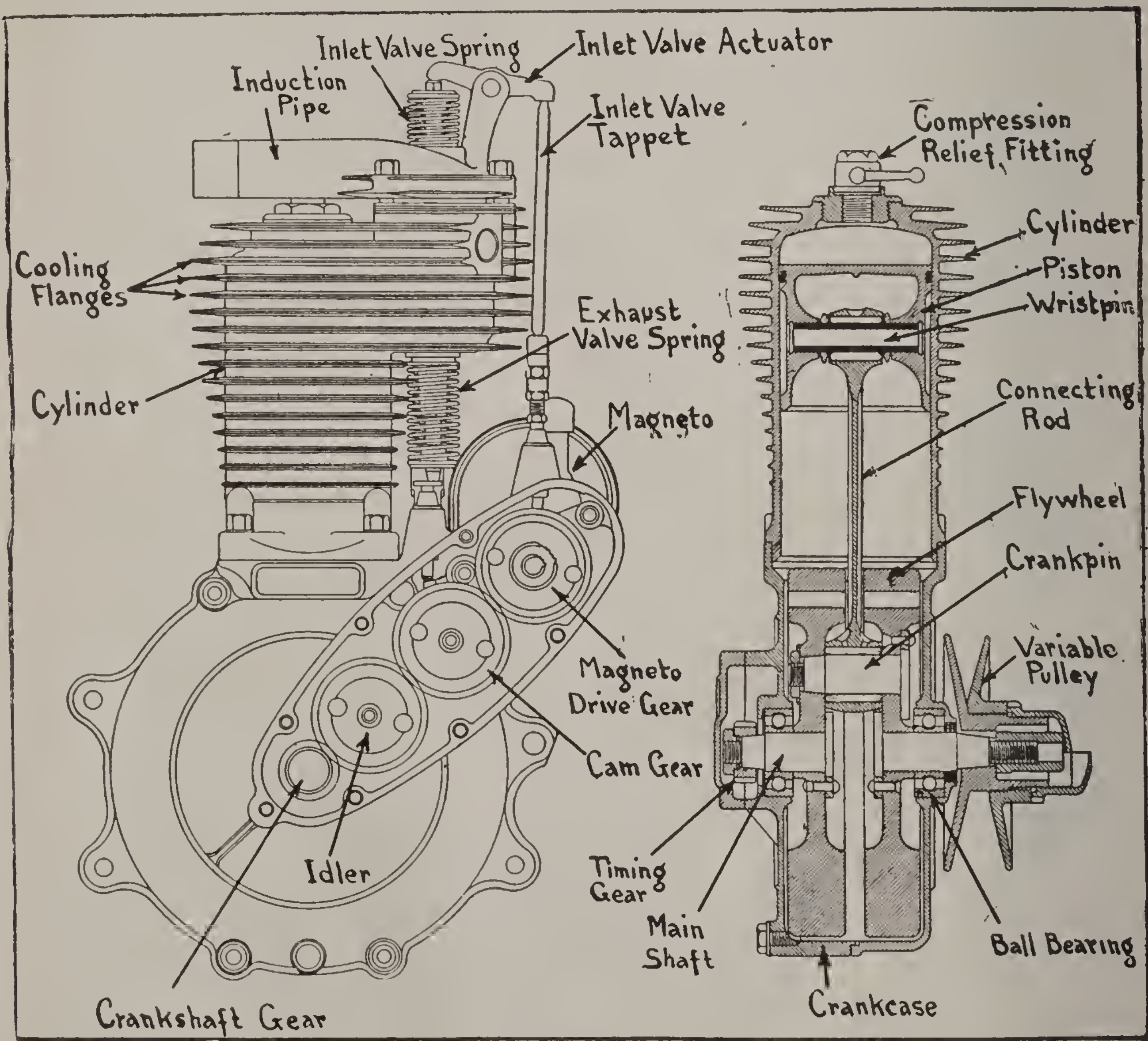


Fig. 57.—Typical Single Cylinder Power Plant of English Design.

cylinder engines joined together so that one cylinder starts to deliver power to the crankshaft where the other leaves off. By using a number of smaller cylinders, instead of a large one, all of the revolving parts may be made lighter, and the reciprocating members are easier to balance because the weight of the parts in one cylinder often

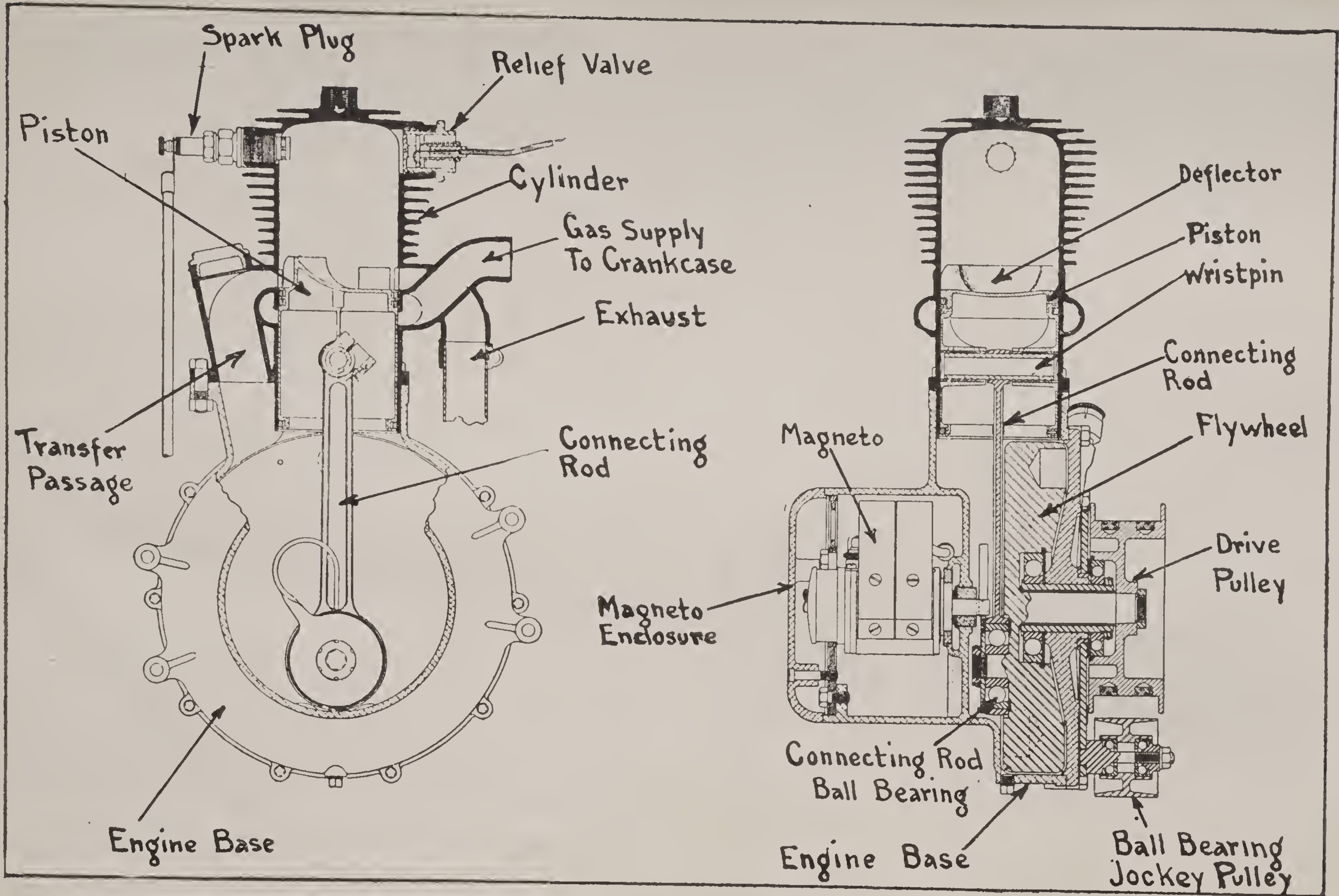


Fig. 58.—Sectional Views of the Schickel Motor, an American Two Stroke Power Plant.

counter-balances the reciprocating mass in the other that works in connection with it.

Multiple-cylinder engines may be run faster than single-cylinder ones of the same power, are not so heavy in proportion to the power developed and produce a more even turning effect at the crankshaft. No matter how well designed the single-cylinder power plant is, the power impulses will come in jerks, and a very heavy fly-wheel member or pair of fly-wheel members is needed to equalize the intermittent power strokes. In a multiple-cylinder engine, where the explosions follow each other in rapid succession, the power application is obviously much more even. A single-cylinder engine will give but one useful power stroke when of the four-cycle type, to every two revolutions of the crankshaft. A two-cylinder motor will give one explosion every revolution, though these are not always evenly spaced, the regularity and evenness of firing being largely dependent upon the arrangement of the cylinders.

Types of Two-Cylinder Motors.—Most two-cylinder motorcycles employ engines of the V-type, i. e., with the two cylinders placed at an angle, and converging to a point at which they contact with the crank-case of the motor. In England, there are a number of machines which employ horizontal cylinders, and one or two makes have been evolved in which the two-cylinder engine has vertical or upright cylinders. We have seen that in a single-cylinder engine considerable dependence is placed upon a fly-wheel which stores up energy and which tends to even up or equalize the intermittent power application derived from but one explosion every two revolutions. We have also learned that multiple-cylinder engines produce more uniform torque because explosions follow each other more rapidly. Where two-cylinder motors are employed, the arrangement of the cylinders and the crank throws with relation to each other has material influence upon the evenness of operation.

For example, in an engine where one of the cylinders fires during one-half of a revolution and the second cylinder produces a power impulse directly after it or while the first cylinder is on its exhaust stroke, it is evident that the engine crankshaft will have to describe almost a continuous revolution before it can receive another power impulse. While the crankshaft receives what would be equivalent to

a power impulse each revolution, in reality it receives two power impulses in one revolution and none during the second. When the cranks are arranged as shown at A, Fig. 60, and the cylinders are vertical, the explosions will follow each other without any appreciable interval, and the only advantage obtained is that the cranks, connecting rods and pistons balance much better than in some other forms. While the vibration due to poor mechanical balance is eliminated to some extent with this construction, a certain unevenness of running obtains on account of the way the explosion occurs.

When the cranks are set on the same plane as shown at B, and both of the pistons move up and down together, it is possible to obtain a

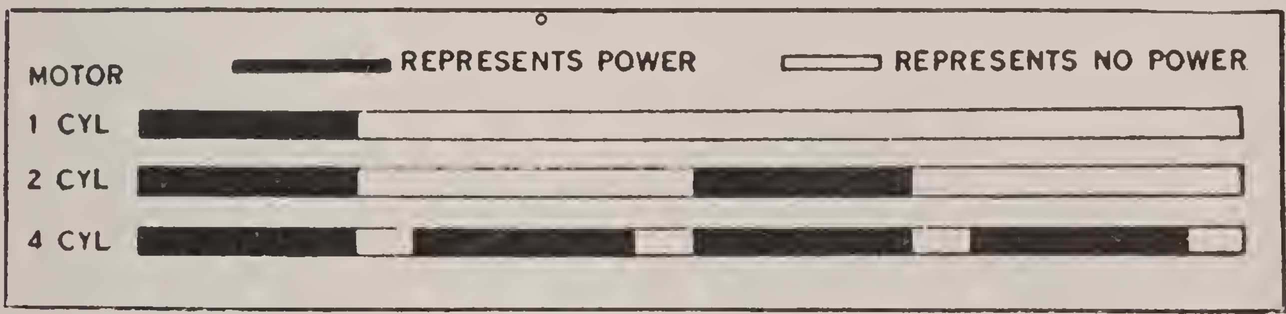


Fig. 59.—Diagram Showing the Advantages of Multiple Cylinder Engines in Obtaining Uniform Power Delivery.

good firing order, i. e., an explosion would occur the first part of the first revolution in one cylinder and the first part of the second revolution in the other cylinder. The explosions are separated by equal intervals of time, and the power application is much more uniform than obtained from the type shown at A. The disadvantage of this method of construction is that the mechanical balance is far from ideal, and counter-weights must be provided to reduce the vibration incidental to both pistons moving up and down together.

With the double opposed motor which is shown at C, the crank-pins are arranged at 180 degrees, and the explosions occur at regular intervals and with the same firing order as prevails in the construction shown at B. This form of motor also has a good mechanical balance. With the V-type of motor it is apparent that the smaller the angle between the cylinders the more evenly spaced the firing sequence becomes, though the mechanical balance is more difficult to obtain when the degree of angularity is small. In a motor with the cylinders

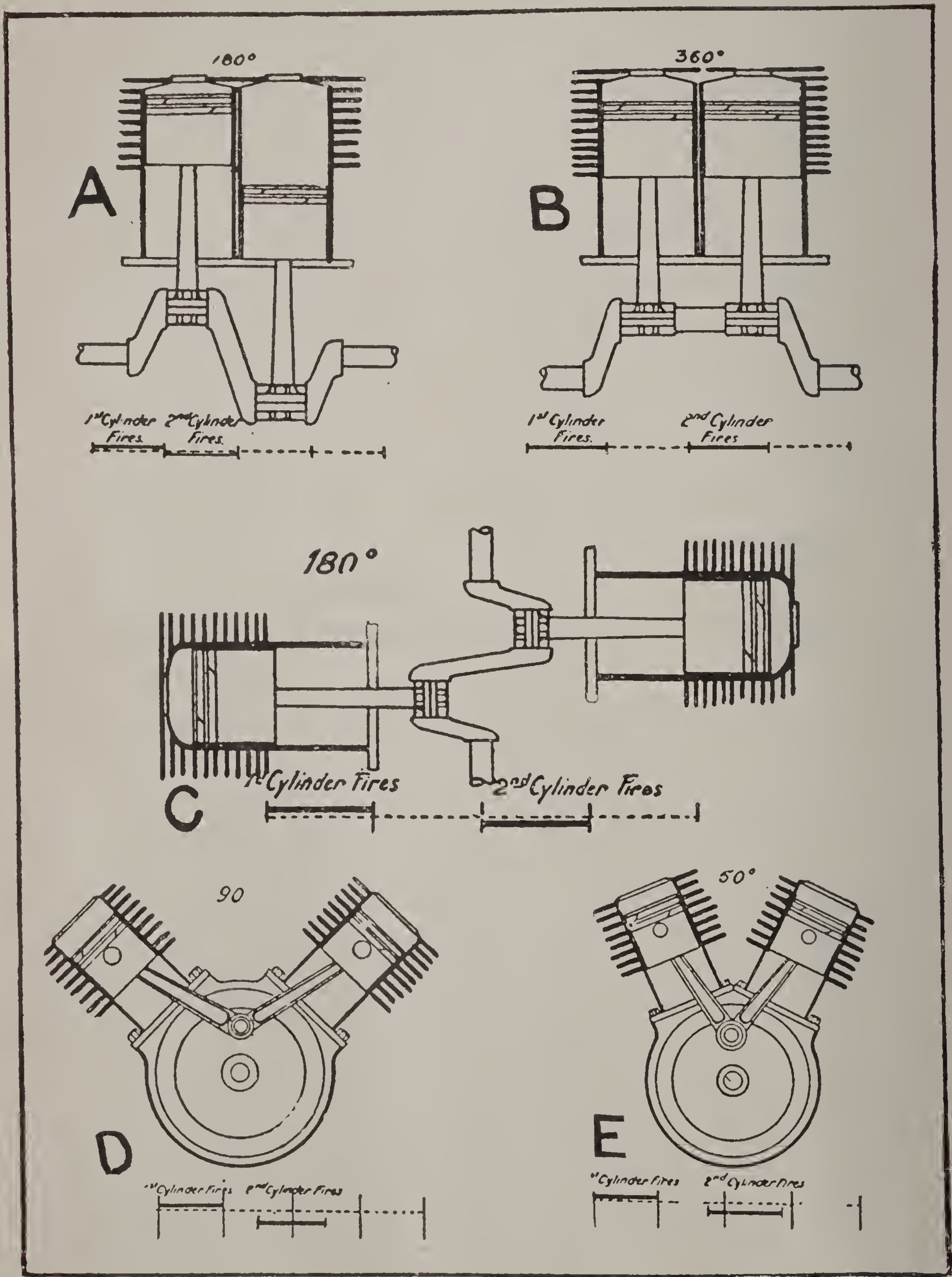


Fig. 60.—Diagrams Illustrating Various Arrangements of Crankshafts on Two Cylinder Motorcycle Power Plants.

at an angle of 90 degrees to each other and with the two connecting rods working on the same crank-pin, the mechanical balance is good but the impulses occur very close together. The better mechanical balance is obtained because the pistons partially balance each other, and a slightly better firing order prevails than in the arrangement shown at A, as there is an interval corresponding to about one-quarter of a revolution between the explosions. When the cylinders are set at an angle of 50 degrees, as indicated at E, the impulses are almost equally divided between the blank spaces as indicated in the diagram. It is possible to have the cylinders set so the explosions are spaced even more regularly, as with the cylinders at 41 degrees, which is said to be the prevailing angle in this country.

The same difficulties are met with in securing good mechanical balance as in the form shown at B, as it is imperative that counter-weights be fitted to balance the reciprocating mass to some extent and reduce vibration. The great advantage of the V-twin motor is that it is a form that may be easily installed in the motorcycle frame, and while the balance is far from perfect it is sufficiently good if the counter-weights are intelligently applied, so a very practical power plant is secured. The original twin-cylinder motorcycle power plant, and one of the first multiple-cylinder gasoline engines, is depicted at Fig. 61, C, and is an adaptation of the single-cylinder form evolved by Daimler, and clearly outlined at A and B. The cylinders in this Daimler motor were placed at an angle of approximately 15 degrees, which is considerably less than present practice.

The engine shown at Fig. 62 is utilized on the Triumph, an English design, and the crank pins are disposed at an angle of 180 degrees. The motor is set in the frame with its crankshaft at right angles to the top frame tube, and not parallel with it as might be expected. The crankshaft carries an outside fly-wheel at one end and a sprocket for chain drive at the other. The inlet valves are at the front of the cylinders and the exhaust valves are at the rear. Both are operated by a camshaft which is driven by a spiral gear from the crankshaft. A typical twin-cylinder V-engine of American design, that may be considered a good example of established practice and which has received wide application, is shown at Fig. 63.

One of the most efficient of the British light-weight motorcycles is

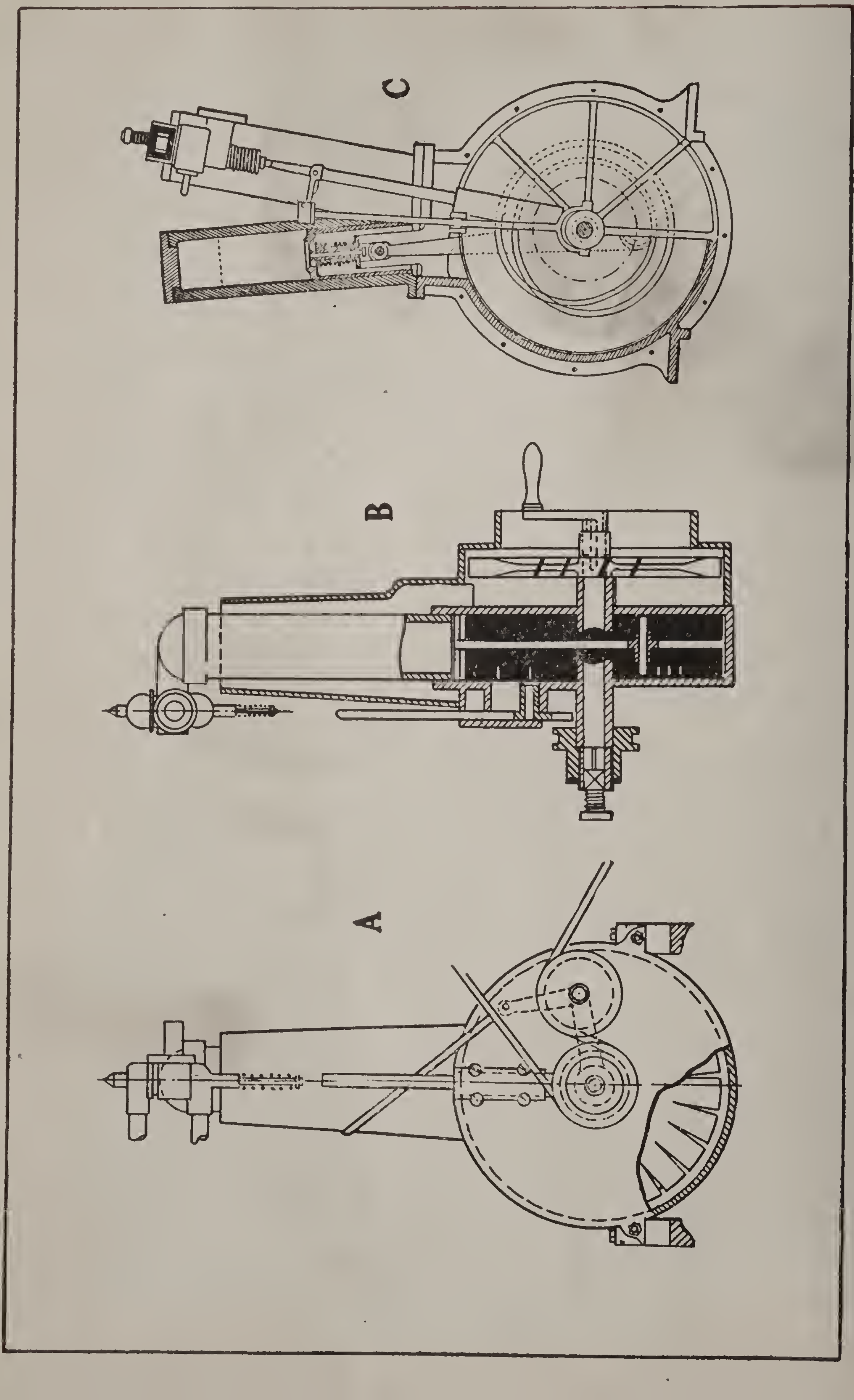


Fig. 61.—Views Showing Construction of Early Daimler Motors, the First Practical High Speed Internal Combustion Power Plants.

provided with the two-cylinder power plant shown at Fig. 64 in which the cylinders are placed horizontally and opposed to each other. The crankshaft, which is depicted in the sectional view of the crank-case at the left of the illustration, has two crank-pins placed at an angle of 180 degrees, and is mounted on ball bearings to insure free running. A distinctive feature of the design is the method of mounting the valves in valve chambers that are inclined so the valves may be actuated from the lower portion of the cam gear case. The method of ribbing the cylinders to secure more effective cooling permits the air draft induced by cycle motion to reach practically all parts of the cylinders, which would not be possible if the flanges were applied in the conventional manner that proves so effective on vertical cylinders. This is a very compact engine that is capable of delivering a uniform torque, and that operates with very little vibration, as the even spacing of the explosions and large external flywheel make for very easy running. The method of magneto and valve-operating cam drive may be readily ascertained as well as other ingenious details of design by studying the reproduction of the maker's engineering drawing that so clearly outlines all details of construction.

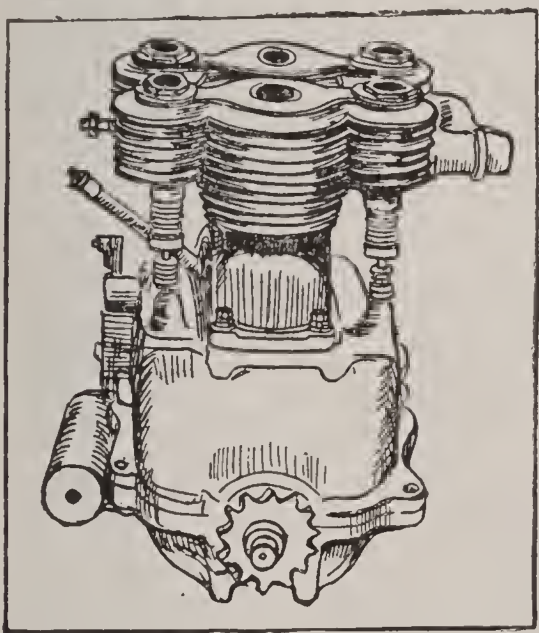


Fig. 62.—The Triumph Two Cylinder Motorcycle Power Plant, an Unconventional English Design.

One of the most distinctive of the unconventional power plants used for motorcycle propulsion is the Scott two-cycle, depicted at Fig. 65. This shows an early model in which a combined air and water cooling system was employed, the liquid being depended on to keep the water-jacketed head cool while the cylinders were provided with cooling flanges of generous proportions. The cylinders are mounted side by side, one each side of the engine center line, which coincides with the center line of the machine. Attention is directed to the small size of the crank-cases, which is necessary to

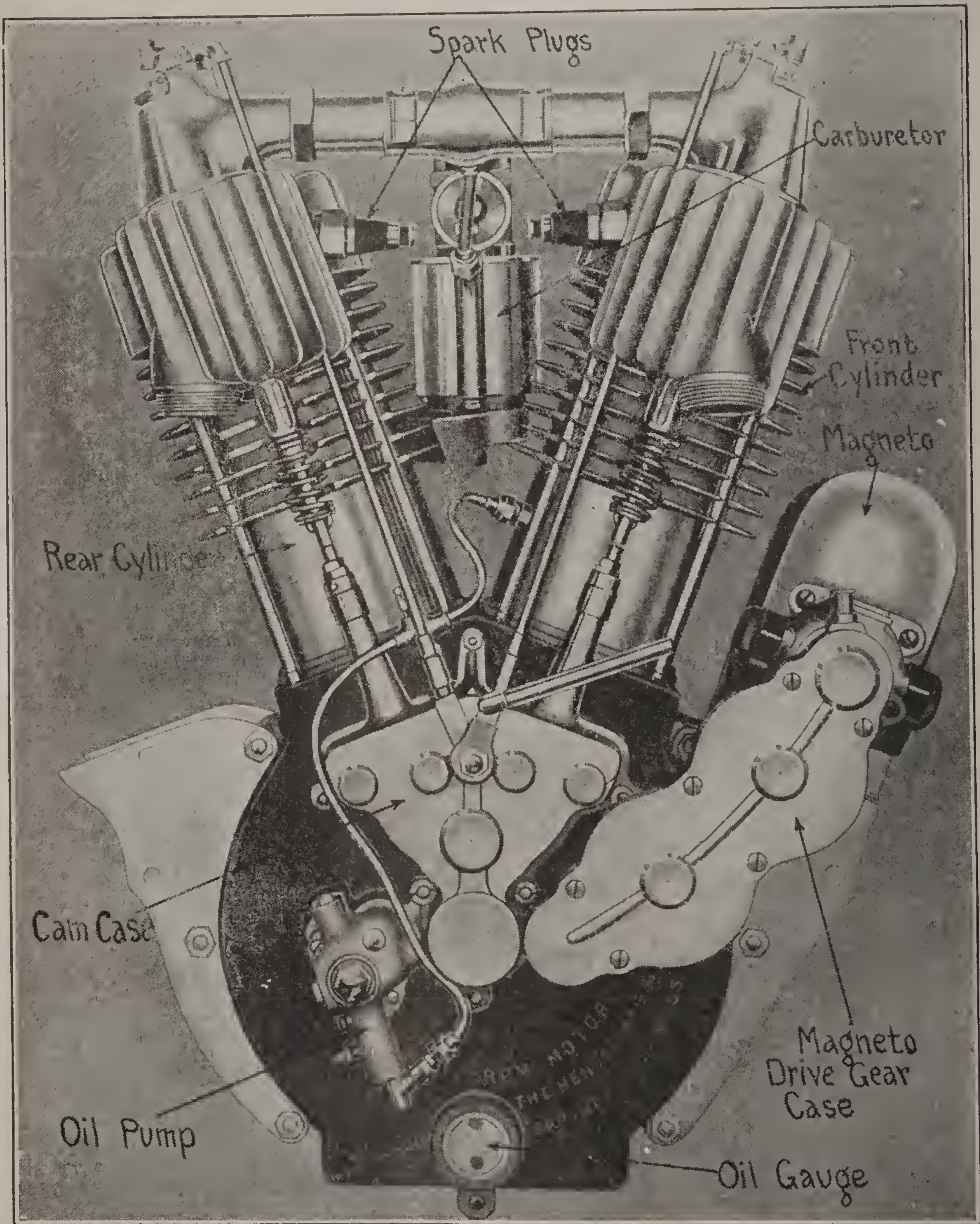


Fig. 63.—Complete Power Plant Assembly Employed on Two Cylinder Indian Motorcycle.

insure adequate preliminary compression of the charge before it is transferred from the engine base to the cylinders. The fly-wheel is mounted between the two cylinders, and carries the driving sprockets on its hub which also forms a connecting coupling between the two

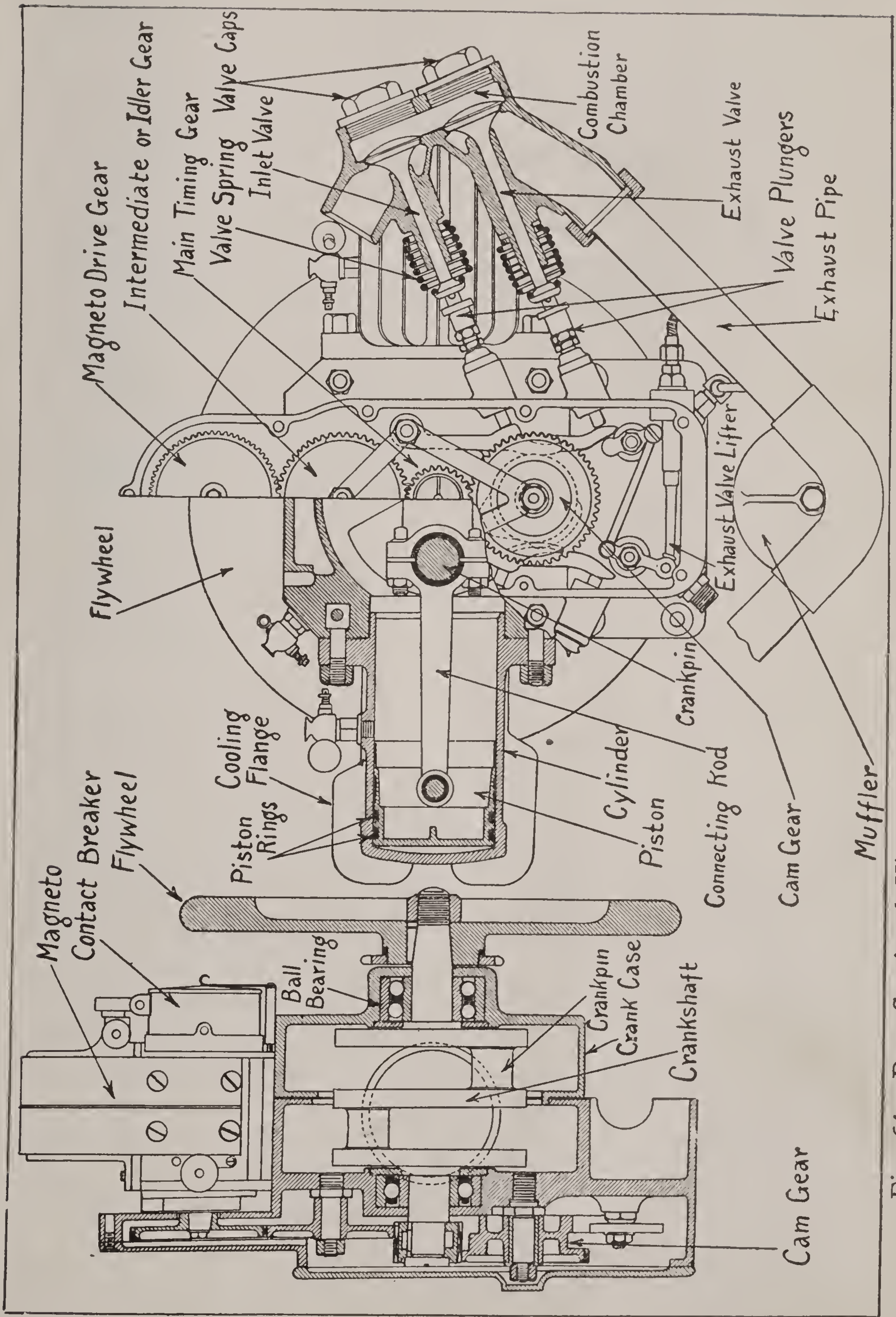


Fig. 64.—Part Sectional Views of the Douglass Opposed Cylinder Motorcycle Motor.

cranks, the assembly forming a built-up crankshaft with the crank-pins at the extreme ends. The arrangement of the ports for the passage of the gases in and out of the cylinder and the method of controlling them by the piston movement is clearly shown in the side sectional view through one of the cylinders. With the piston in the position shown, the exhaust ports are fully open for discharging the burnt gases and the inlet ports at the opposite side are also uncovered to permit the gas compressed in the engine base to by-pass into the cylinder through the transfer passage. The piston is provided with a deflector to direct the entering fresh gas to the top of the cylinder, and prevent it passing out of the open exhaust ports opposite the point where it first enters the cylinder. When the piston reaches the top of its stroke, another row of ports is opened by the bottom of the piston and the crank-case is charged with gas. When one piston is up, the other member is down and the pistons balance each other. An explosion is obtained in each cylinder every revolution, which indicates that this engine should provide the same even torque as obtained from a four-cylinder engine of the four-stroke pattern, inasmuch as the crankshaft receives two impulses each revolution.

Four-Cylinder Forms.—The real value of a multiple-cylinder motor is more apparent when four or six cylinders are used, because in the former one obtains a power impulse every half revolution of the fly-wheel, while in the latter three power strokes are delivered every revolution. The diagram presented at Fig. 59 compares in a graphic manner the useful power impulse of engines having one, two and four cylinders respectively. The shaded parts represent periods where power application obtains, while the unshaded portions represent no power. In the one-cylinder engine, it will be evident that less than one-quarter of the cycle represents useful energy. In the two-cylinder engine the explosions may be evenly spaced, but are separated by appreciable spaces where no power is developed.

Even in the four-cylinder engine there are periods (corresponding to the early opening of the exhaust valves on the power stroke) where no useful energy is directed against the crankshaft. The torque or power application is uniform enough for all practical purposes, except where the utmost refinement is desired, as in high-grade motor car power plants. In the six-cylinder engine there are no periods in the

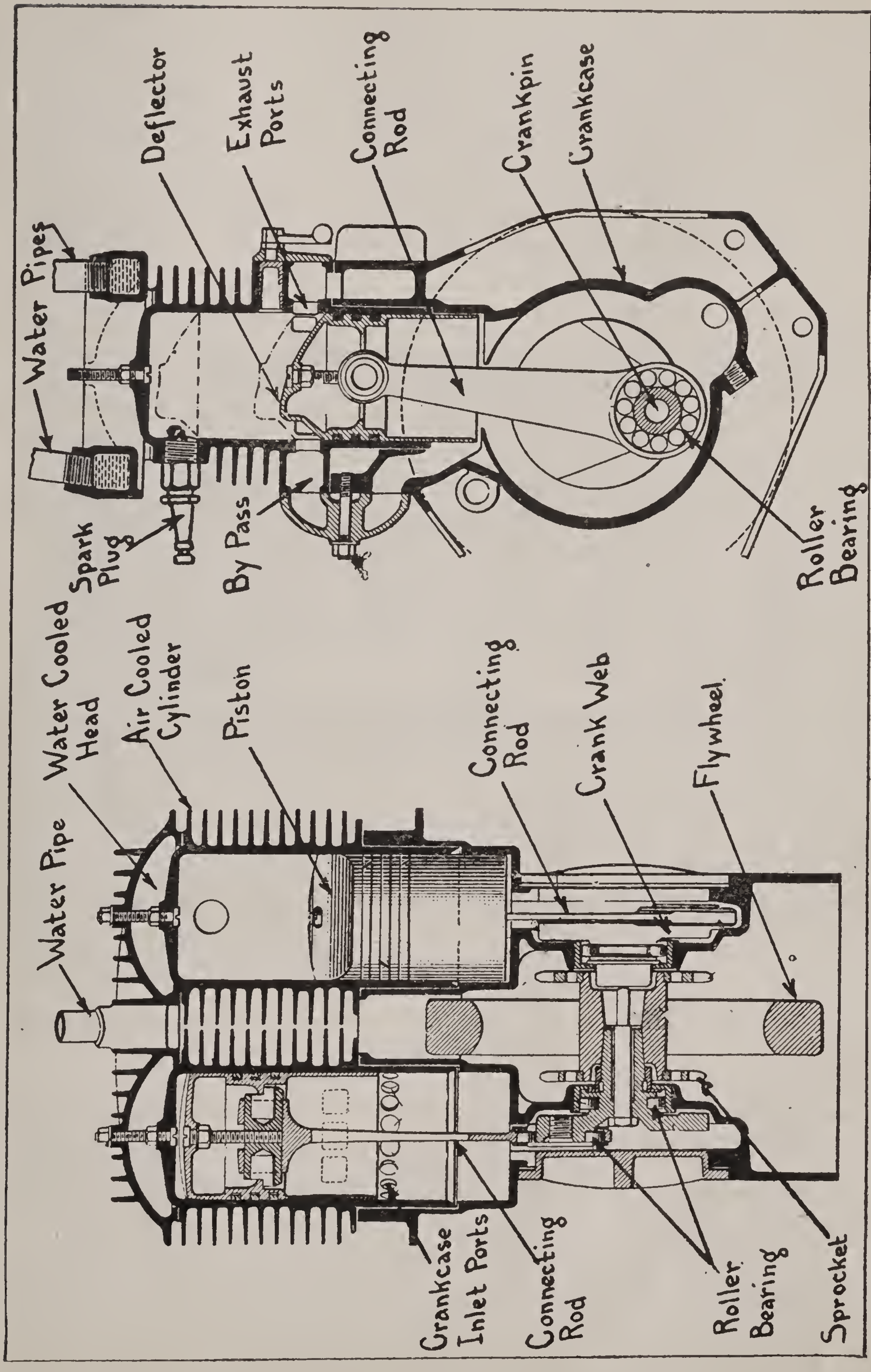


Fig. 65.—Sectional View Showing Arrangement of Parts in Scott Two-cycle Power Plant.

cycle of operation where the crankshaft is not positively driven. In fact, the explosions overlap each other, and a very smooth-acting power plant is obtained. For motorcycle service, however, a four-cylinder motor will prove to be very satisfactory, and will operate with minimum vibration, and, in view of the very satisfactory operation of the ordinary V-twin power plant, it is open to question if the four-cylinder motor offers marked enough advantages to compensate

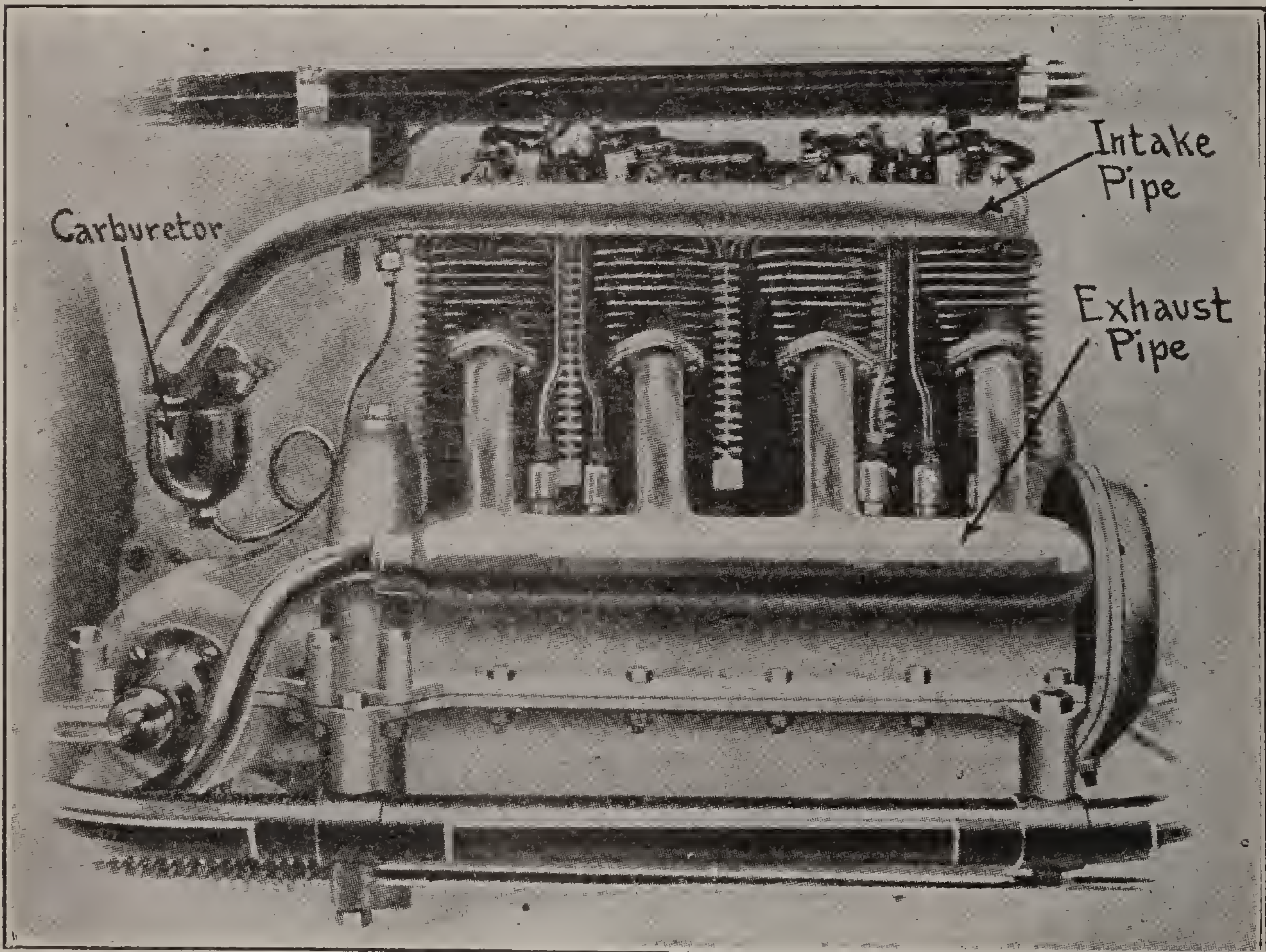


Fig. 66.—Manifold Side of the Henderson Four Cylinder Motorcycle Power Plant.

for its added complication. Of course, there are riders who want the best there is, regardless of cost, and where maximum silence, freedom from vibration and even power application are desired, it is evident that the four-cylinder power plant best fulfills the requirements.

The four-cylinder motor utilized in the Henderson motorcycle, an American design previously illustrated, is shown installed in the frame at Fig. 66 when viewed from the valve side, and in section to show practically all the details of construction at Fig. 67. In general

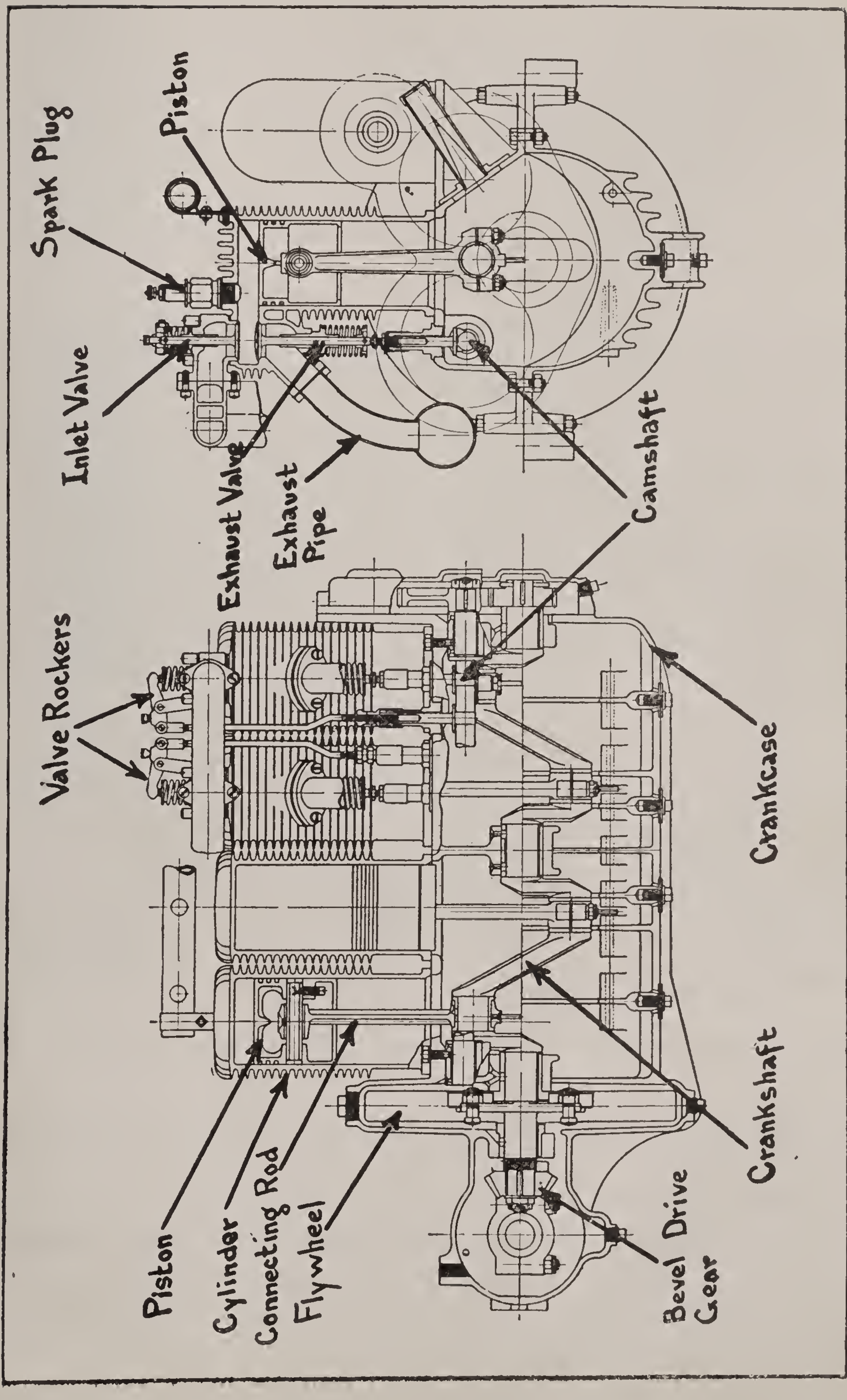


Fig. 67.—Sectional Views Defining Internal Construction of Henderson Four Cylinder Motorcycle Power Plant.

arrangement of parts, this power plant follows the lines established in automobile practice. A sectional view of the F. N. four-cylinder engine, which shows the practical application of a five-bearing crankshaft and the arrangement of the crank-pins, so two pistons are going down while the other two are on their up stroke, is presented at Fig. 68. It will be noticed that the Henderson crankshaft, while it has four crank throws, is a three-bearing form, having one main journal at the center and one at each end, whereas the F. N. design has a

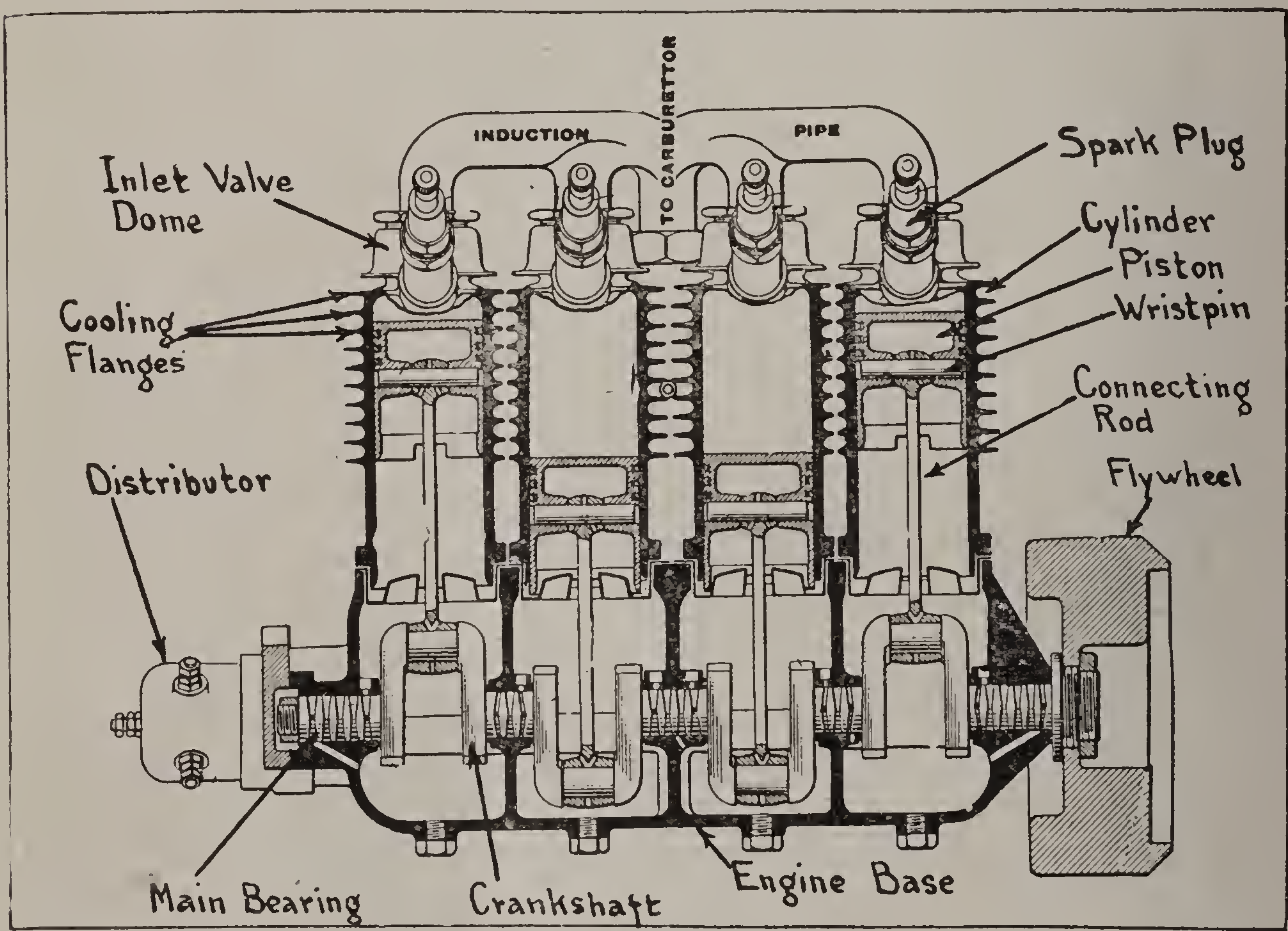


Fig. 68.—Sectional View of the F. N. Four Cylinder Motor.

bearing between all crank throws as well as at the ends of the crankshaft.

Power Plant Support and Location.—We have seen that in the early days the designers considered the gasoline motor an attachment to the bicycle, and that it was disposed of in numerous ways, few of which were really satisfactory and effective. The average rider who is familiar with present practice may not consider that power plant location or support is much of a problem, and in view of the remark-

able unanimity of opinion regarding power plant placing in modern machines, this view is, to a certain extent, justified, though those who have been identified with motorcycle construction long enough know that considerable experimentation was necessary before the designers of power-propelled cycles were able to place the power plant to the best advantage. As soon as designers realized that the power plant was an important component part of the vehicle and that it should

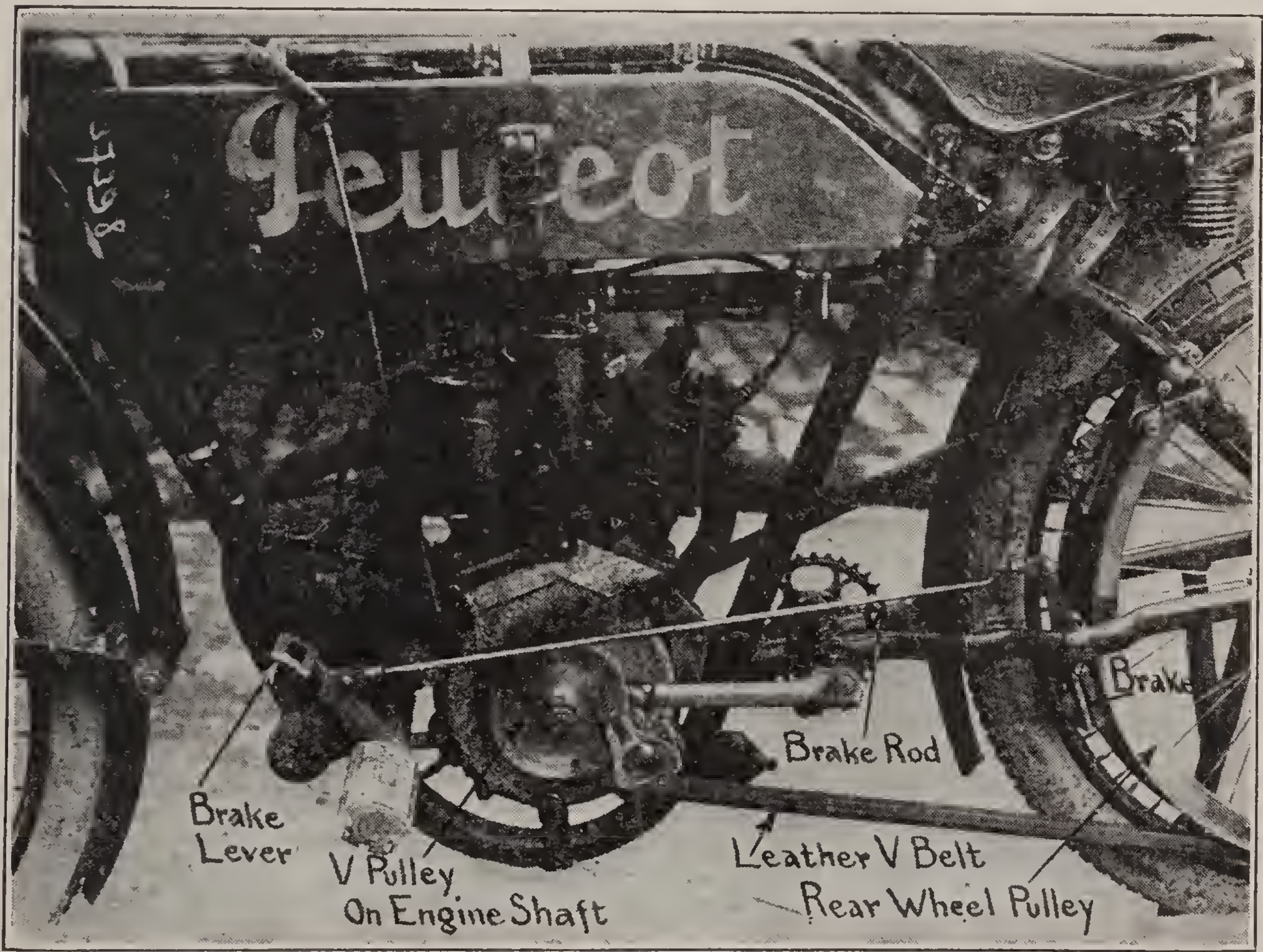


Fig. 69.—The Peugeot (French) Motorcycle Power Plant Installed in Frame.

be incorporated in the design, the diamond frame was abandoned, and special frame constructions evolved, in which provision was made for the secure anchorage of the engine base.

The non-technical reader has no comprehension of the amount of stress present at the points of motor support and why these must be amply strong, but some idea may be gained if one considers that all the time the motor is driving the rear wheel there is a reaction or pull on the engine fastenings that tends to loosen it from its sup-

ports. This force is equal to that exerted by the motor to drive the motorcycle. In addition to the torque reaction, as this force is called, there is an added twisting stress due to the common system of taking the power from one side of the motor only, which tends to turn the motor on a vertical axis, whereas the torque reaction tends to rotate the power plant on a horizontal axis at the center line of the crankshaft. Besides securing ample strength in the design of motor supports, it is also important to mount the power plant in a way that

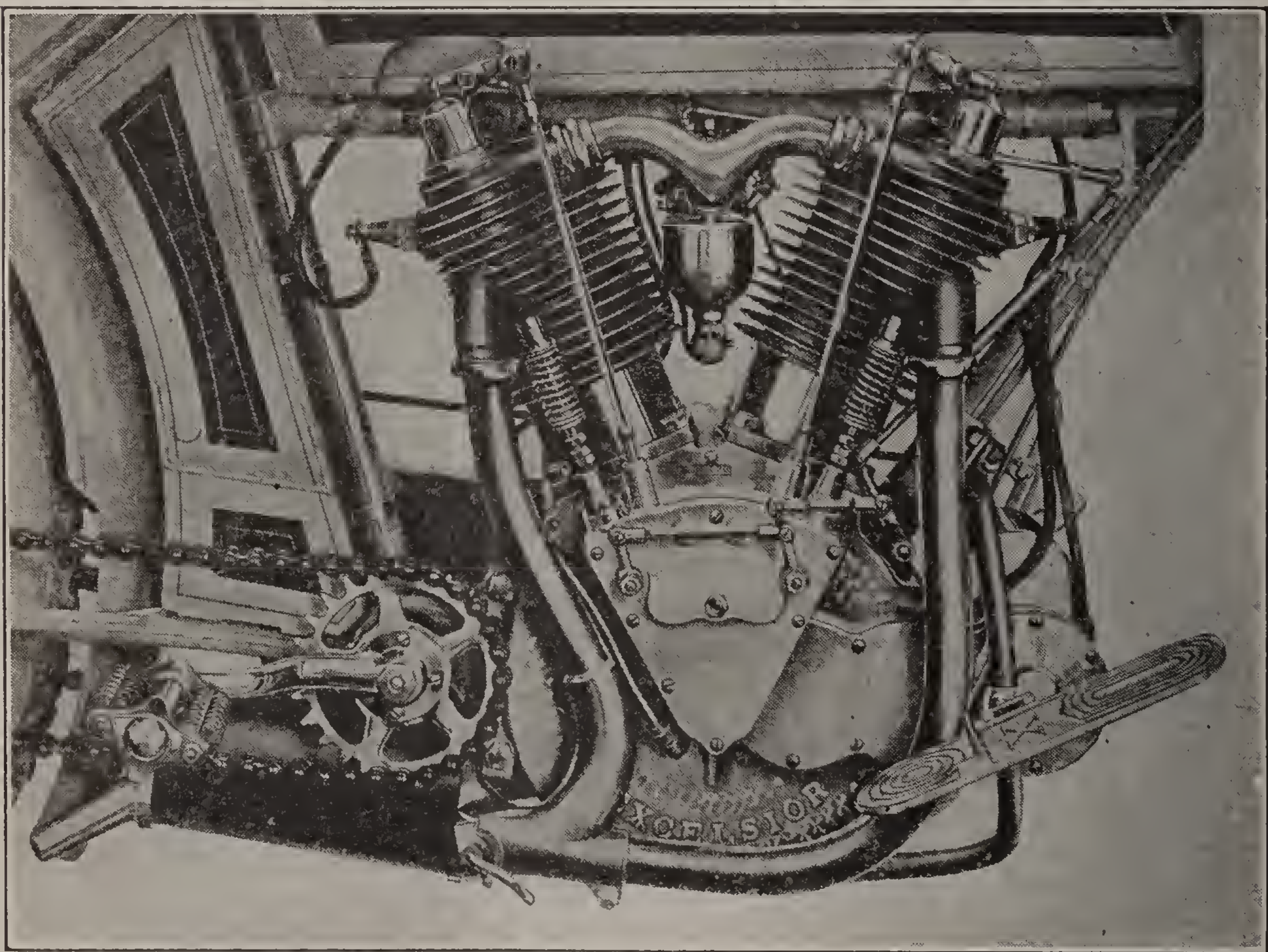


Fig. 70.—Valve Side of the Excelsior Twin Cylinder Power Plant.

will permit of its ready removal from the frame for repairs. It is also desirable to have the motor fastened securely enough so the frame structure will resist its tendency to vibrate at all speeds except at the critical speed for which the balance weights were calculated, therefore some makers anchor the cylinders to the frame tubes as well as the engine base.

The loop frame design is widely employed because the motor may be removed from the frame without disturbing the integrity of the

frame structure. Designers who favor this method of motor support also contend that the engine base is better protected when mounted above a substantial frame tube than when suspended so it forms part of the frame. The installation of the Peugeot engine in a loop frame of substantial design is shown at Fig. 69, and in this construction it is not believed necessary to anchor the cylinders to the frame in any way. When the cylinders are not secured to the frame and a loop

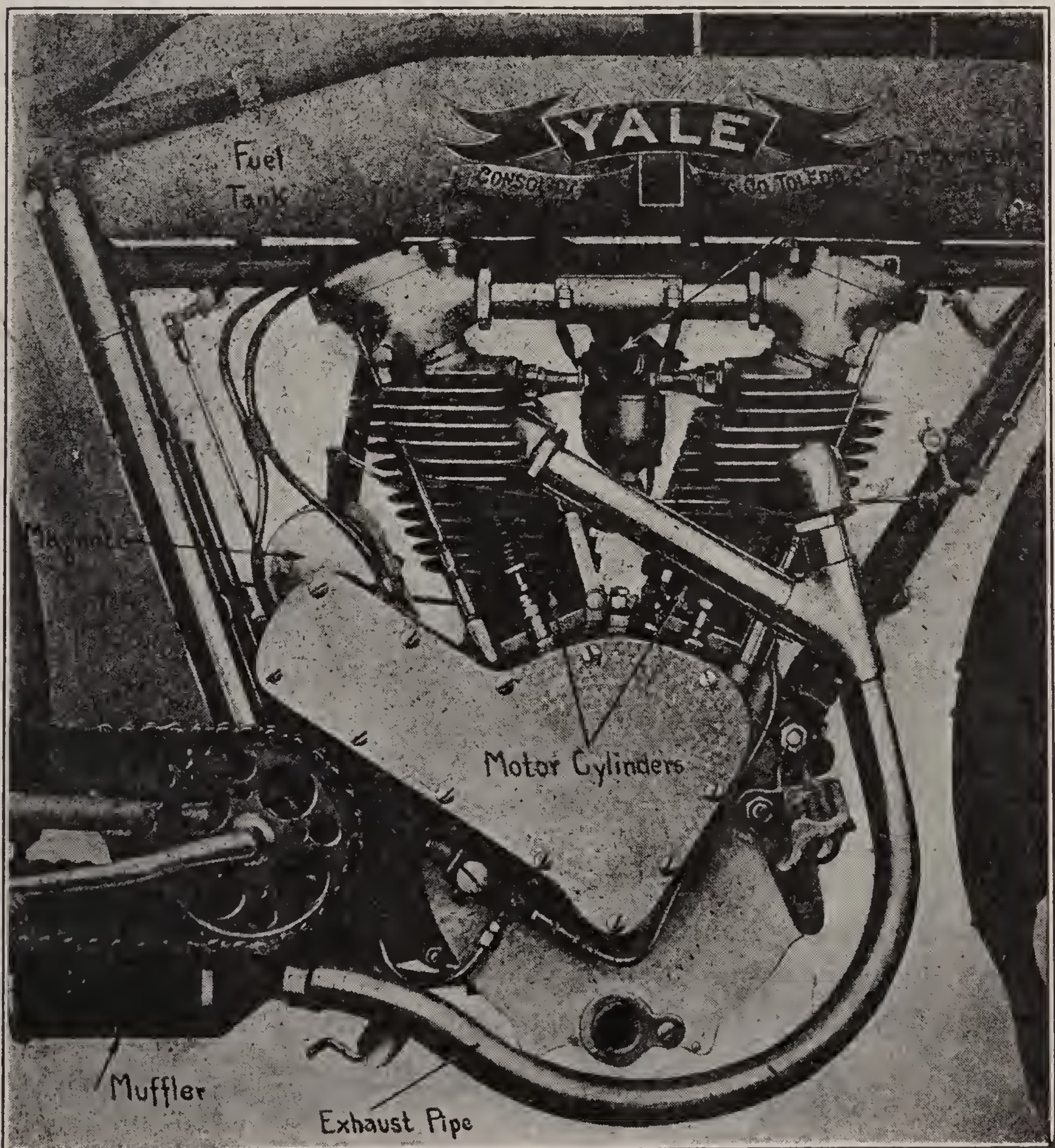


Fig. 71.—Valve Side of the Yale Twin Cylinder Power Plant. Note Design of Cooling Flanges, Which Permit an Unobstructed Flow of Air Over the Cylinders.

frame is employed, it is possible to remove a cylinder from the crank-case, in many cases, without removing that member from the frame. The crank-case may be made lighter when it is not an integral part of the frame, and should the frame weave there is no strain imposed on the cylinder as that member is free to move slightly even though the crank-case is securely held.

In the Excelsior machine, the power plant forms a part of the frame, and is depended upon to give the frame strength, as that member would not be very strong with the engine base removed. Of course, the makers contend that there is no need for strength when the motor is not in place because at such times the motorcycle is out of commission, but there is always the liability of springing the lower portions of the tubes when they are not supported if the frame is carelessly handled when the motor is not in place. A loop frame is much stronger than the forms shown at Figs. 70 and 71, when the motor is removed, and there is no possibility of distorting the frame. The Excelsior motor is supported at five points, and, when in place, the structure is very strong. As the lower portion of the crank-case is exposed, it is made heavier and stronger than in the forms where it is protected by the frame tube loop, and this added strength has a favorable bearing on general rigidity of the assembly. The motor is supported at three points on the crank-case, two being at the rear and one at the front, and each of the cylinders is attached to the frame member below the tank by substantial clips. This method of attachment is very valuable in open-frame machines where there is some opportunity for frame weaving, especially if the power plant retaining bolts loosen even a slight amount.

While the attachment of the cylinders steadies the motor wonderfully, and holds it in place, some who do not favor this construction contend that the expansion of the cylinders when heated renders it imperative to have the upper end of the cylinders free to move under its influence. This objection seems to be more theoretical than real because machines with the cylinders anchored have given just as good service in practical application as those that were free to expand unhindered.

The Yale power plant, shown at Fig. 71, is anchored to the frame in much the same manner as the Excelsior, as the rear end of the

engine base is attached to substantial plate members firmly secured to the crank hanger, while the front portion is provided with a lug fitting between the jaws of the fork attached to the lower end of the diagonal frame tube. The water-cooled power plant of the Regal-Green motorcycle, an English design depicted at Fig. 72, also forms part of the frame assembly and is fastened in much the same manner as the Excelsior and Yale power plants. The method of installing

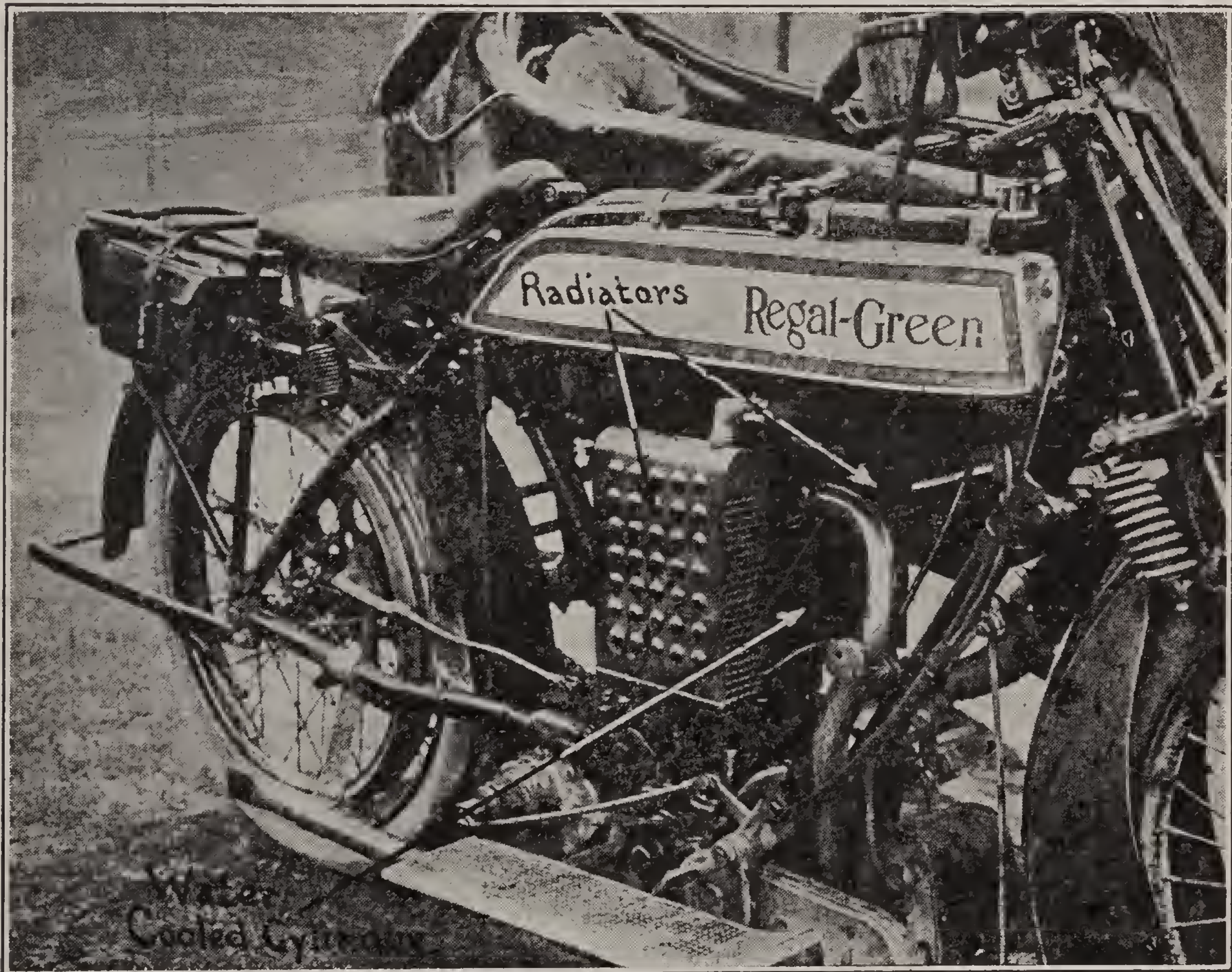


Fig. 72.—Showing the Application of the Precision Water-Cooled Motor on Regal-Green Motorcycle.

a four-cylinder power plant is exemplified at Fig. 66 which shows the fastenings that hold the Henderson motor in place. The lower portion of the frame is composed of two parallel tubes which converge at the front end to the steering head, and as there is sufficient space between them for the comparatively narrow crank-case possible with the small four-cylinder design, this member may be provided with suitable lugs or arms cast integral which rest on the frame tubes and be securely

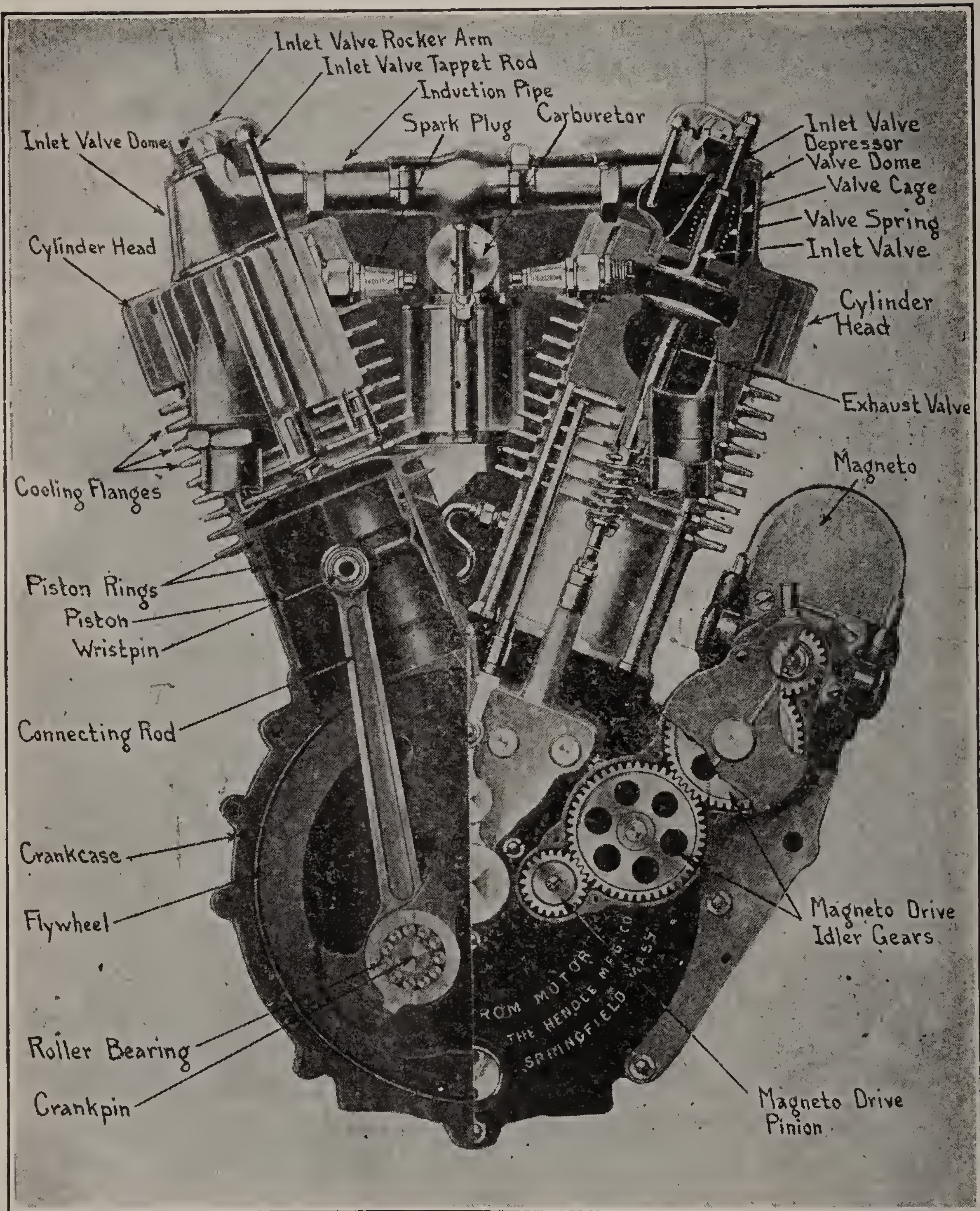


Fig. 73.—Part Sectional View Showing Arrangement of Important Internal Parts of Two Cylinder Indian Motorcycle Power Plant.

retained by bolts or studs passing through the tube and crank-case extensions. A very secure four-point suspension system is obtained in this manner, and owing to the smooth running and lack of vibration, incidental to the employment of a four-cylinder engine, it is not

necessary to anchor the cylinders to the frame in any way except by the necessary bolts which keep them in place on the engine base.

Motorcycle Engine Parts and Their Functions.—In order that the non-technical reader may become thoroughly familiar with the principles of operation and appearance of the various parts of motorcycle power plants a number of forms will be described and the functions of the various parts made clear. The engine at Fig. 73 is shown in part section as the crank-case and the lower part of one of the cylinders is cut away, while the other cylinder is sectioned through the valve chamber. The engine consists of an engine base, which also serves as a crank-case to which the two cylinders and all other parts are attached. The members inside the cylinders that reciprocate up and down, and which receive the force of the explosion, are termed "pistons," and there is one in each cylinder. The reciprocating movement of these pistons is converted into a rotary movement of the crank-pin by means of connecting rods which oscillate at their upper ends on wrist pins that pass through suitable bosses in the piston. The inlet valve, which is the member through which the gas is admitted into the cylinder is carried in a valve cage which in turn is installed in an air-tight dome which is utilized to press the valve cage firmly against the seating in the cylinder head. The inlet valve is normally kept seated by a valve spring, and is opened at the proper time by the inlet valve depresser, which is worked by the inlet valve rocker arm. The rocker arm is operated by a tappet rod which extends to the top of the cylinder from the timing gear case. The exhaust valve is the member controlling the port through which the burnt gases leave the cylinder, and this is raised from its seat at the desired period in the cycle of operations by a push rod that bears against the lower portion of the valve stem. The exhaust valve is kept seated in the same manner as the inlet valve though the spring is stronger.

The spark plugs which are inserted in the combustion chambers are employed to explode the gas with a spark derived from the magneto which is driven by a train of gearing from the crankshaft. The cylinder heads, as well as the cylinders, are provided with cooling flanges and are held in place on the cylinders by bolts extending to the crank-case which also serves to hold the cylinders firmly by clamping them between the heads and engine base. The fly-wheels are

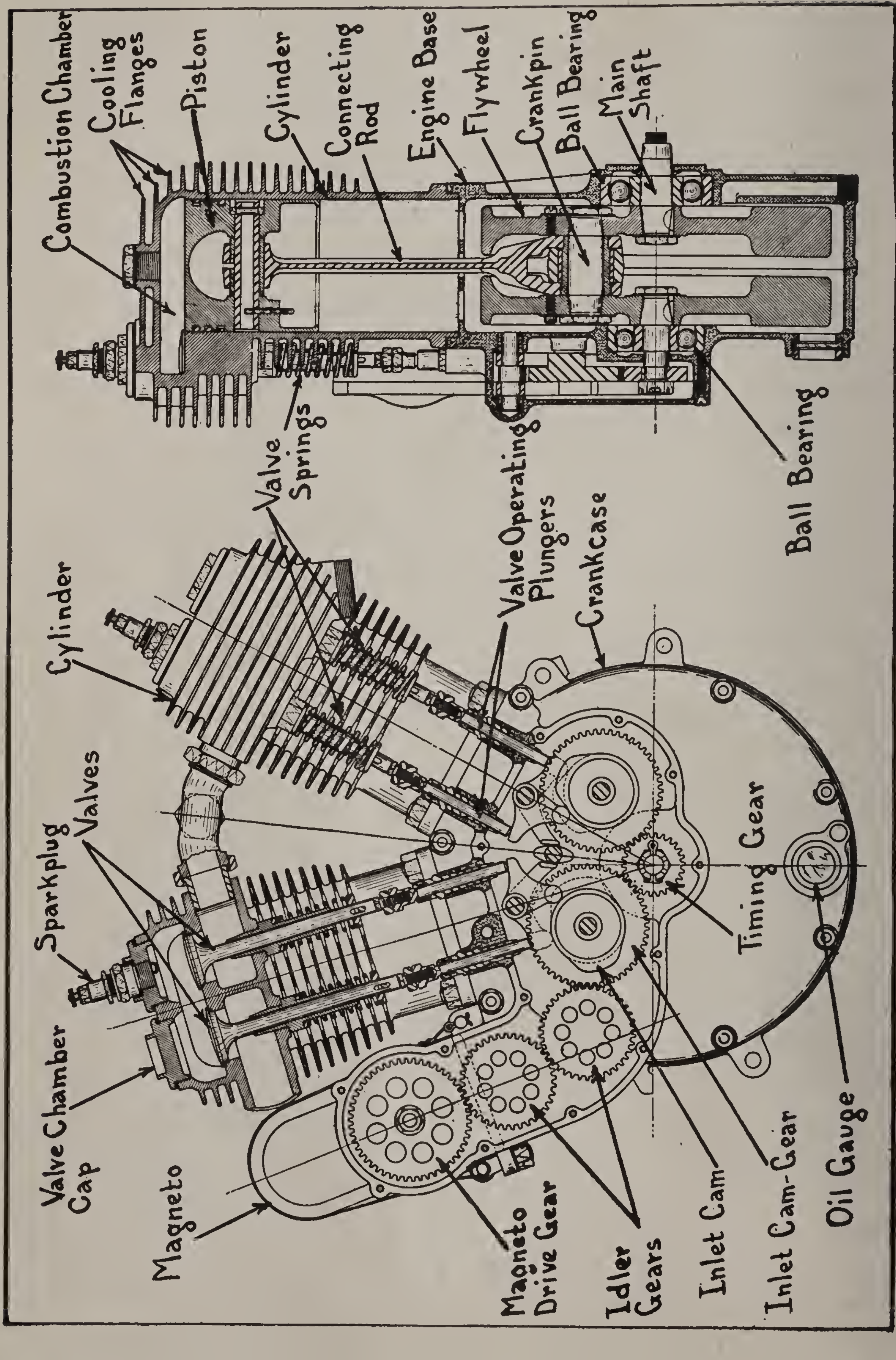


Fig. 74.—Sectional View Outlining Construction of the Reading-Standard Twin Cylinder Power Plant.

employed to steady the action of the engine, and to store up power during the idle strokes in order to keep the engine parts in motion at such times as there is no useful pressure exerted against the piston tops. The carburetor that supplies the explosive gas to the cylinders is securely attached to an induction pipe that joins the inlet valve domes of the two cylinders.

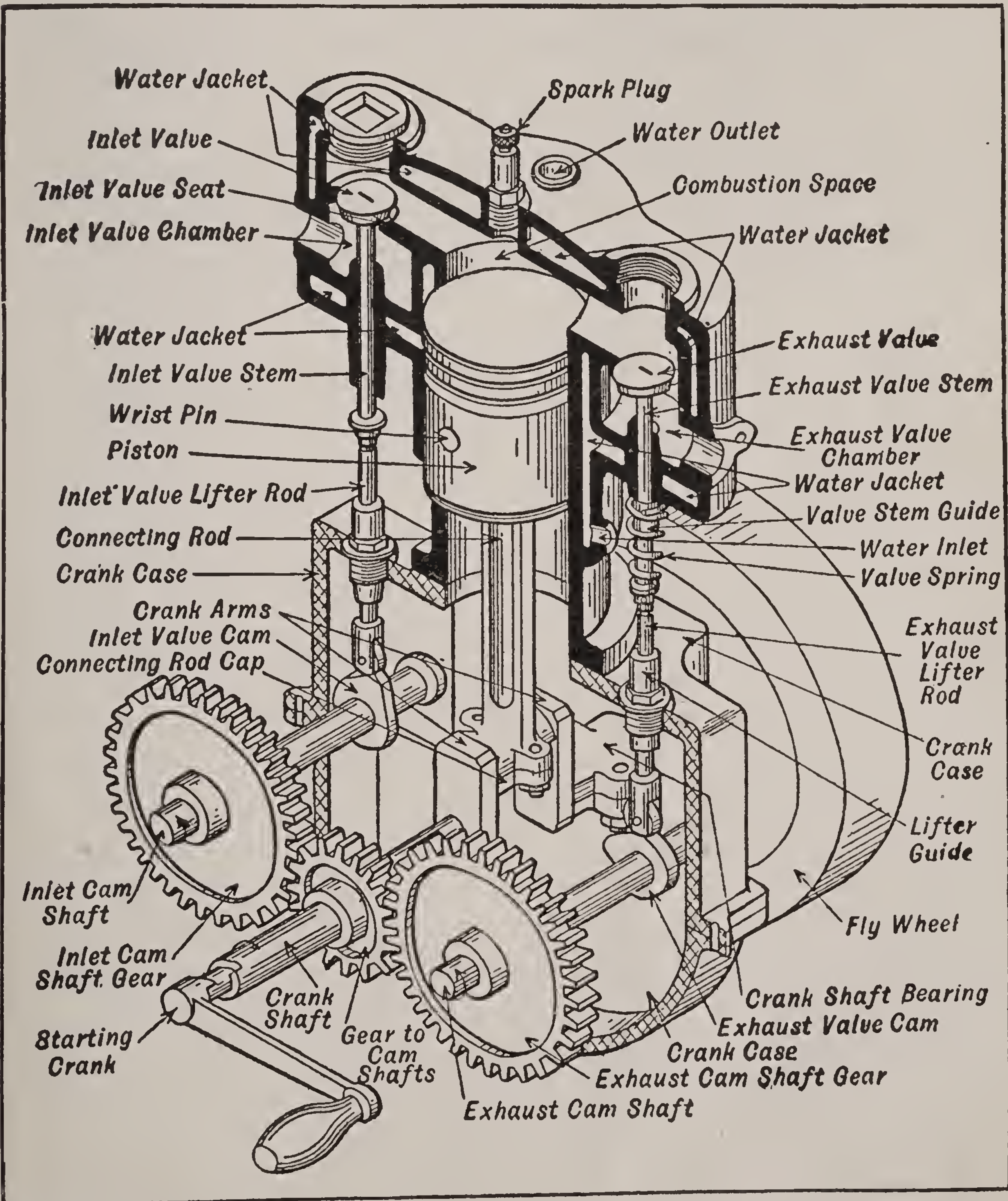


Fig. 75.—Diagram Showing Principal Parts of Single Cylinder Water-Cooled T Head Power Plant.

The twin-cylinder power plant, shown at Fig. 74, is practically the same in operation as that previously described though the cylinder design and location of valves is very much different. In the side view, the valve-operating mechanism and the magneto drive gears are clearly outlined, while in the sectional view at the right, the arrangement of the fly-wheel and crankshaft assembly and the method of supporting it on ball bearings is outlined. The engine at Fig. 75 is a simple T-head form with water jacket, and is a type that is used to some extent on light cars and cyclecars. All parts are clearly indicated, and in view of the explanations previously given regarding the duties of these parts, the reader should have no difficulty in understanding the relation they bear to each other in the complete power plant, and the part they play when the engine functions.

CHAPTER III.

CONSTRUCTION AND DESIGN OF ENGINE PARTS.

Methods of Cylinder Construction—Advantages of Detachable Heads—Material Employed and Methods of Finishing—Combustion Chamber Design—Relation of Valve Placing to Engine Efficiency—Bore and Stroke Ratio—Influence of Compression on Power Developed—Offset Cylinders—Automatic and Mechanical Valves—Valve Design and Construction—How Valves are Operated—Valve Timing—Pistons and Rings—Wrist-Pin and Connecting Rod Arrangements—Crankshaft Forms and Fly-wheels—Engine Base Design and Construction—Plain and Anti-Friction Engine Bearings.

Methods of Cylinder Construction.—There are two general designs of cylinder construction followed by motorcycle designers, namely, the one-piece and the two-piece types. A typical cylinder of the one-piece pattern is depicted at Fig. 76 in connection with the piston, its wrist-pin and one of the piston rings. The cylinder in place on a single-cylinder power plant of Spacke make is shown at Fig. 77, while the part sectional view at Fig. 78 shows clearly the one-piece construction. In the early days, before the development of satisfactory cylinder-head packing, and when sheet asbestos and copper were the only packing mediums known for obtaining a gas-tight joint between the cylinder and cylinder head, there was considerable trouble experienced due to loss of compression and power through leaky packings. It was found that the sheet asbestos did not have sufficient strength to resist the high pressure, and the sheet metal packings were too hard to conform to any irregularities that might exist in the seating between the combustion chamber and cylinder when these were separate castings held together by clamping bolts. The complaints voiced by the riders against the two-piece construction led many manufacturers to cast their cylinders and valve chambers in one piece instead of depending upon any kind of a packing, as necessary in the two-piece construction.

While the one-piece cylinder offers advantages of some moment, in reducing the liability of leakage by eliminating a packed joint, it has the disadvantage of rendering the piston considerably more inaccessible than was the case where the cylinder head could be removed from the cylinders and expose the piston top so carbon deposits could be removed easily without taking the cylinder off of the engine base. With a one-piece construction, it is, of course, necessary to remove

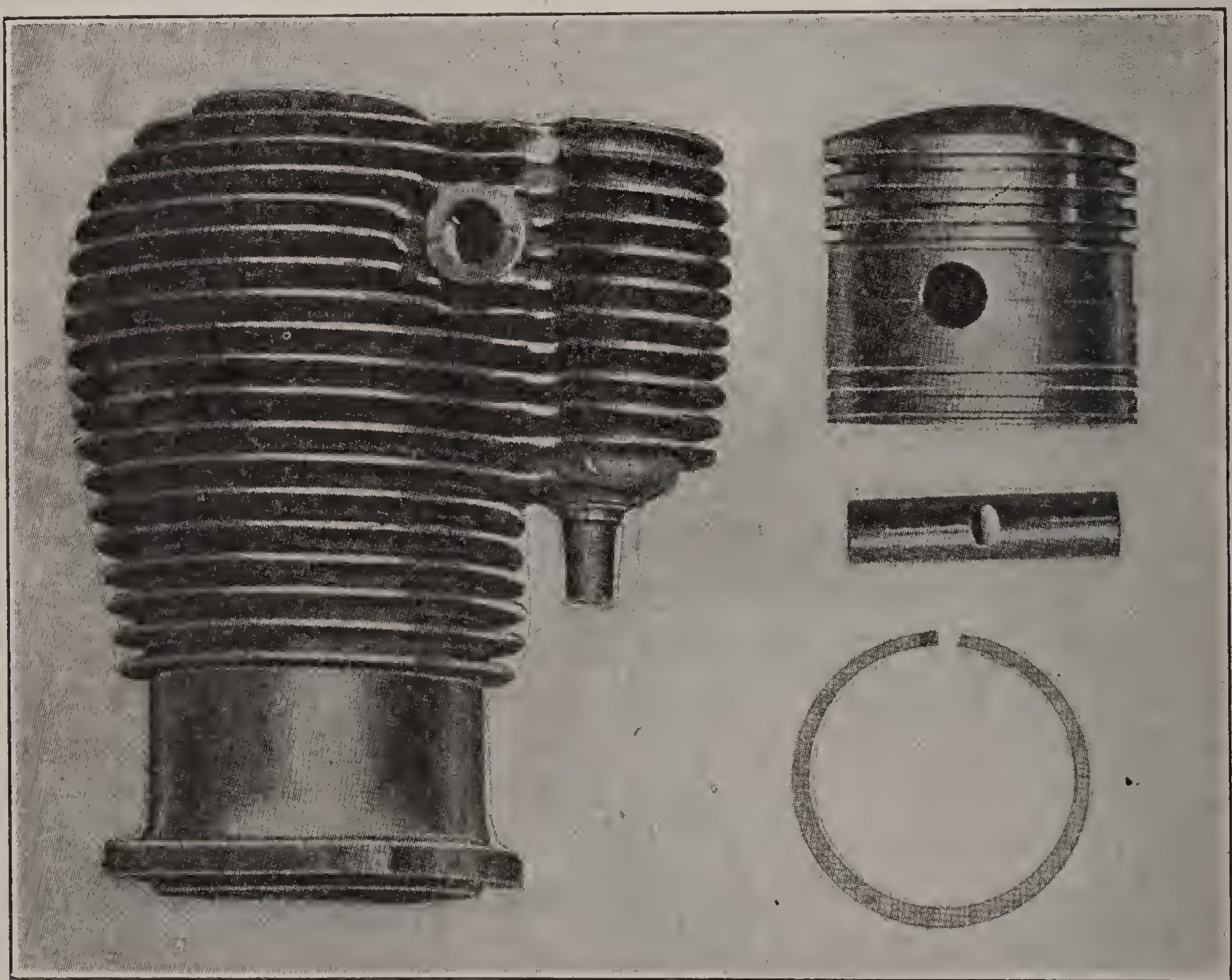


Fig. 76.—One-Piece Cylinder Construction, Also Dome Head Piston, Wrist Pin and One of the Eccentric Piston Rings Used With It.

the cylinder. Another advantage possessed by the detachable combustion head construction is that it is possible to grind the valves in very easily when that member is removed, as it can be taken to the bench and placed in a vise where it can be held securely and worked on to advantage. In grinding the valves, particularly the exhaust, in most cylinders of the one-piece pattern, if one does not wish to take the entire cylinder assembly from the crank-case to gain access to

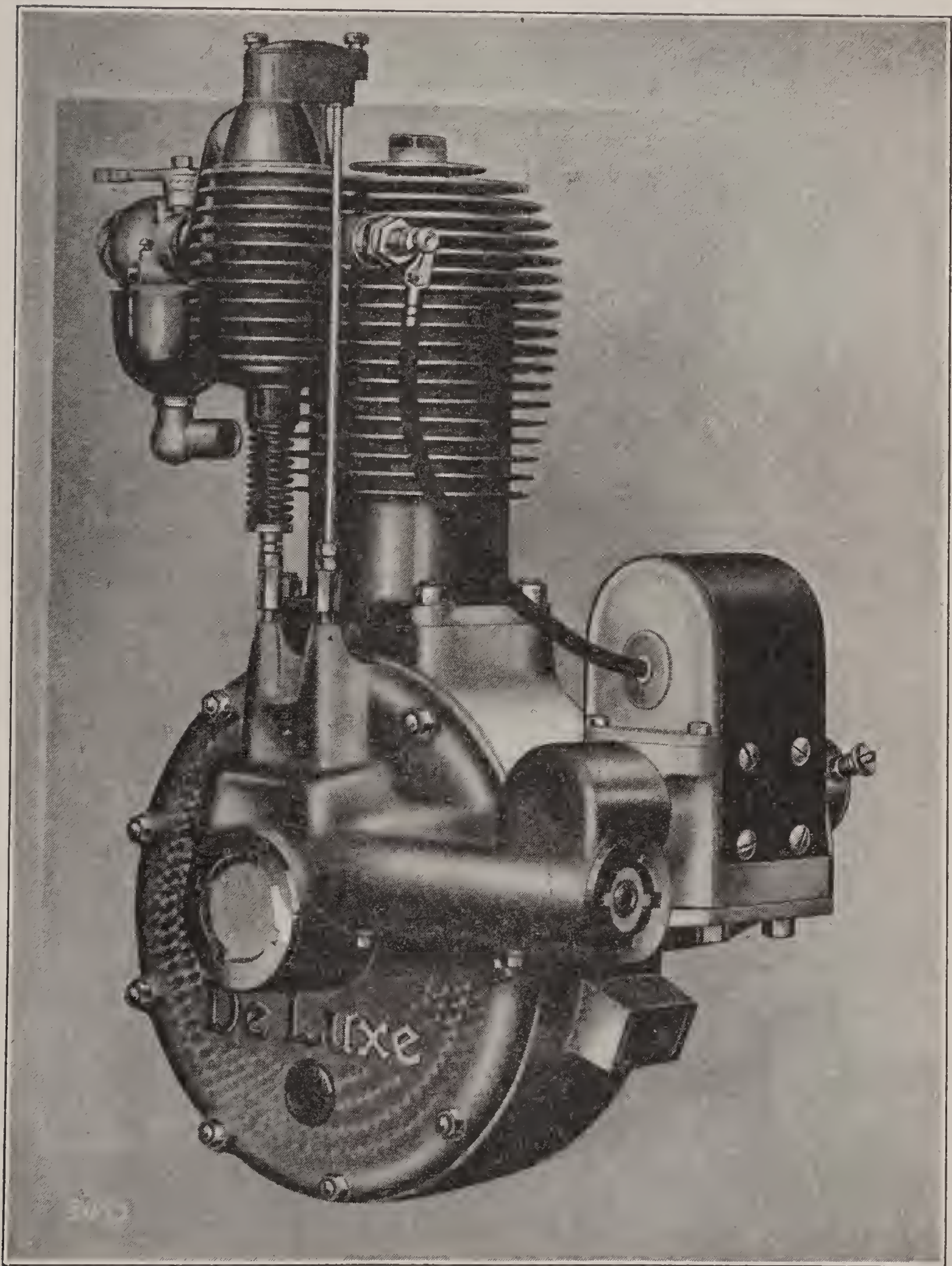


Fig. 77.—Exterior View of the De Luxe Single Cylinder Motorcycle Power Plant, Showing Practical Application of One-Piece Cylinder.

the cylinder from the engine, the work must be done with that member in place, and there is always a possibility of having some of the abrasive used in valve grinding find its way into the cylinder interior, where it would do considerable harm by causing scratches that run the length of the cylinder, and which interfere materially with retaining proper compression. Of course, it is not necessary for the rider to get the abrasive into the cylinder, but at the same time many inexperienced persons, when grinding valves, have not realized the importance of keeping the emery from the cylinder interior, and trouble has been experienced owing to unintentional neglect of this essential precaution.

The inlet valve of most motorcycle engines is carried in an easily detachable cage which incorporates the valve seat, and it is, therefore, easy to grind this member at the bench. There are cylinder forms, however, of the T or L design where both inlet and exhaust valves seat directly in the valve chamber. In cases of this kind there would, of course, be just as much liability of emery getting into the cylinder while grinding the inlet valve as when fitting the exhaust member. The one-piece cylinder construction has the material advantage of considerably simplifying the motor construction as it eliminates the extra piece or casting that is necessary if the combustion chamber is separate from the cylinder.

Advantages of Detachable Cylinder Heads.—The sectional view of the engine depicted at Fig. 79 shows clearly the construction of a detachable head and the method of holding it in place on the cylinder casting. It will be observed that the cylinder head not only includes the combustion chamber but also incorporates the extension in which the valves are located. The cylinder is a simple ribbed cylindrical member which can be easily handled in casting and machining. It is held in place against a seating on the engine base by long bolts or studs which screw into the crank-case at the lower end, and which have nuts at the upper end to clamp the detachable head firmly in place. In the engine shown, three bolts are used, but owing to their disposition but one of the bolts shows in this view. It will be evident that the cylinder acts as a spacer between the detachable head and the crank-case, and that the retention bolts serve to draw the head and crank-case together, thus clamping the cylinder firmly

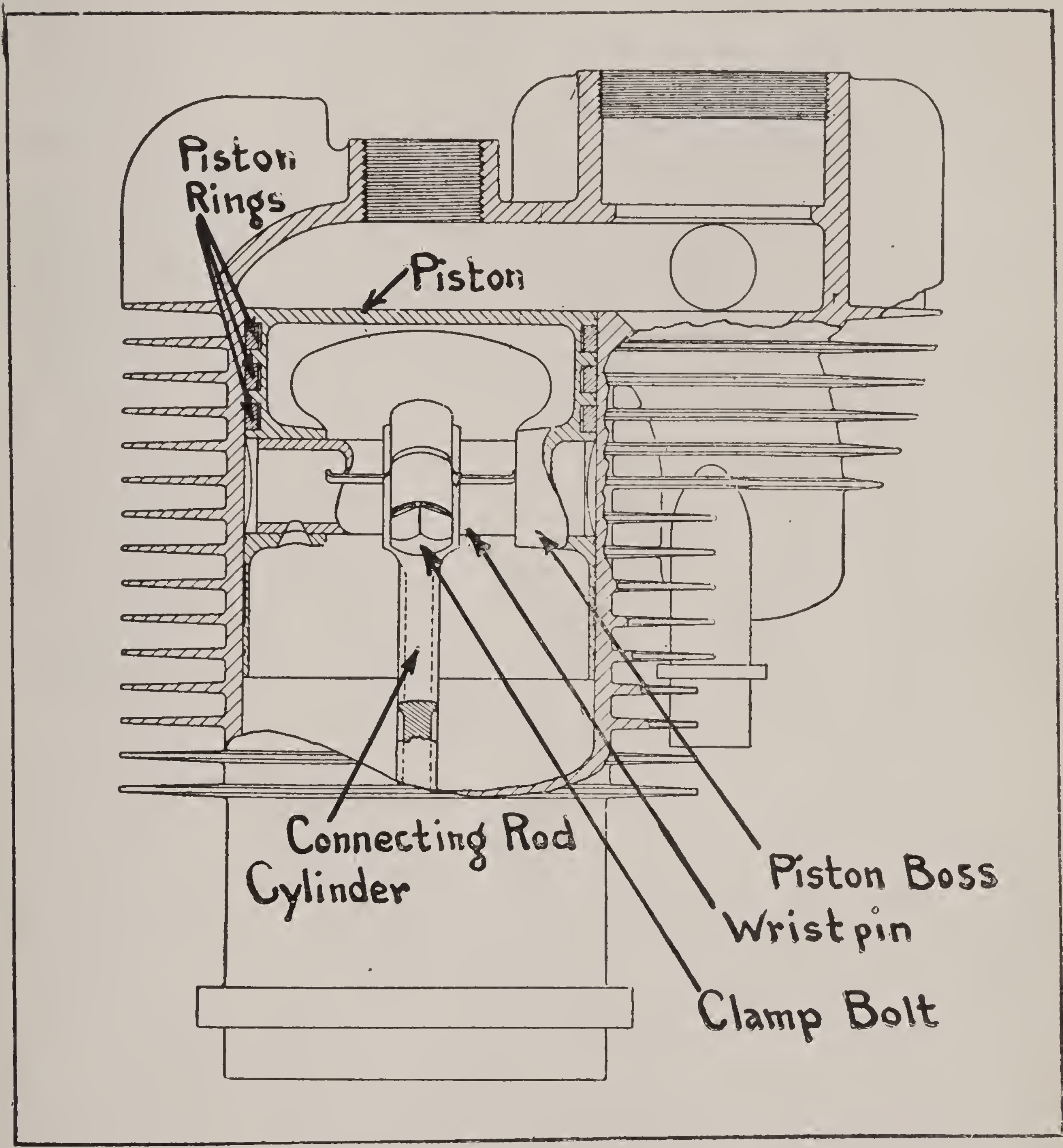


Fig. 78.—Part Sectional View of One-Piece Cylinder, Defining Construction of Piston, Wrist Pin, and Upper End of Connecting Rod.

in place. The two-piece construction is quite practical at the present time because great improvements have been made in the construction of gaskets or packings.

The sheet asbestos formerly used had the advantage of being compressible and thus forming a very good packing, though the light rings of this soft material were very fragile and could not be used more than once, as they were invariably destroyed when the cylinder head was

removed from the cylinder. The hard copper did not bed itself properly, and unless the retaining bolts were tightened down practically the same at the three points on the cylinder head there was very apt to be a compression and explosion leak because the inflexible material did not permit the head to bear down against the gasket resting on the cylinder. As both forms of packing had their merits, it occurred to some designers to try a combination of the two materials and a gasket or packing ring was evolved that consisted of sheet asbestos ring enclosed in a shell of very light sheet copper or brass. The metal held the asbestos in place firmly and provided an item of strength that was desirable. At the other hand, the light gauge of the copper used did not interfere materially with the flexible properties of the asbestos, and the gasket readily conformed to any slight irregularity or roughness on the cylinder or cylinder head seat. This form of gasket practically eliminated the troubles which were present in the old detachable head engine, and many designers continued to use the two-piece construction.

In addition to the big feature of providing a degree of accessibility to the piston top and combustion chamber interior for removing carbon deposits without dismantling the entire engine, there was retained the added advantage of having a cylinder head available that permitted grinding in the exhaust valves without danger of abrasive matter getting into the cylinder. Another feature of merit in connection with the detachable head construction is that cylinder replacements are less expensive than is the case when a one-piece cylinder is employed. As will be evident, practically all of the depreciation will exist at that portion of the cylinder that is traversed by the piston. Therefore, with the one-piece construction when the cylinder became worn to a point where it was desirable to replace it because the thinness of the metal in most motorcycle cylinders does not permit of reboring or grinding to remove deep scratches, it was necessary to throw away a perfectly good combustion head and valve seatings, which had depreciated but slightly in service. With the detachable cylinder construction if that member wears it can be cheaply renewed, and the combustion head can be used just as well with the new cylinder as with the old one. It is also possible to machine the interior of the combustion chamber more easily with the separable head con-

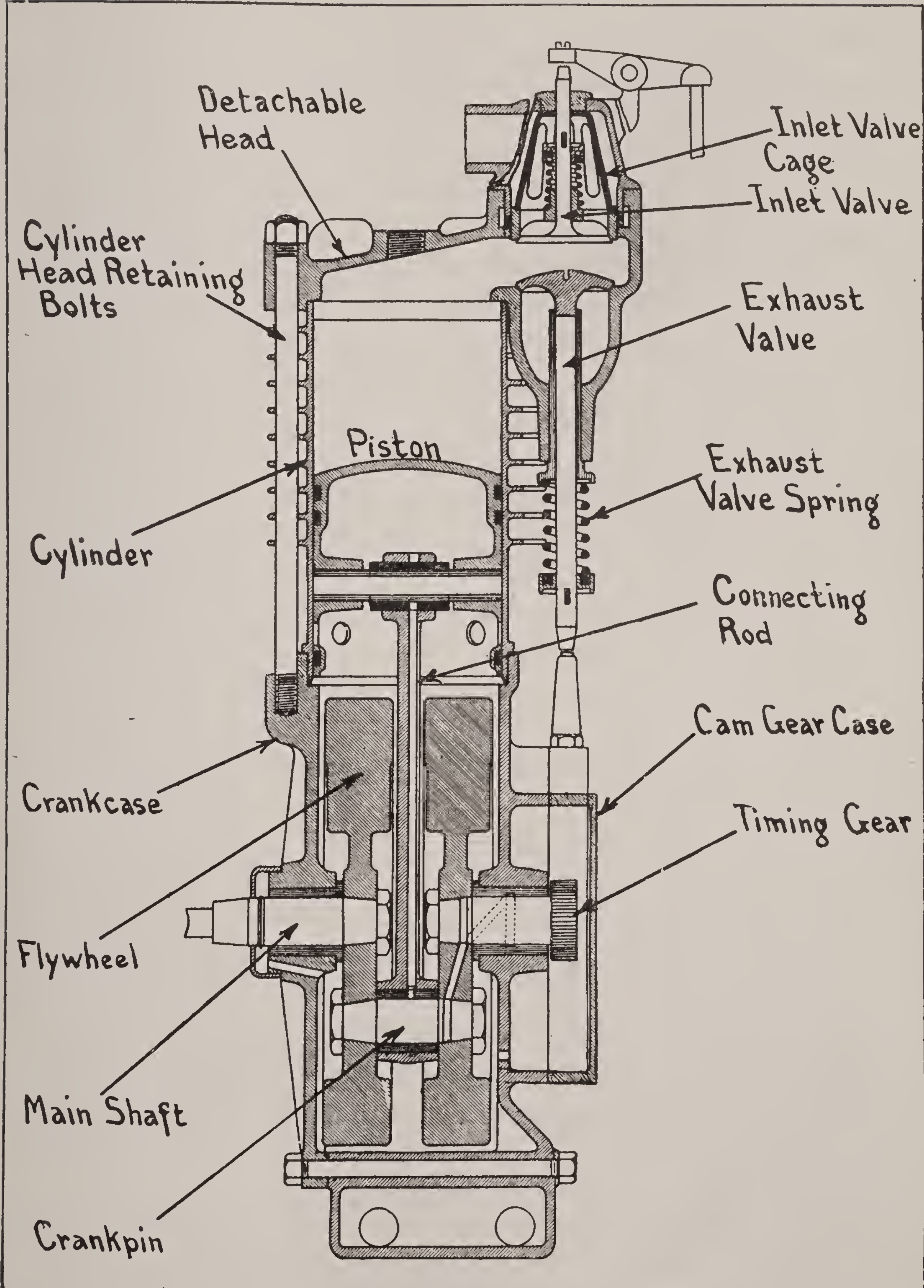


Fig. 79.—Sectional View of Single Cylinder Motor of English Design Using Detachable Cylinder Head.

struction. This is a feature of some importance, especially in overhead valve types.

Materials Employed and Method of Finishing.—Cylinders are invariably made of close grain gray iron which contains considerably more phosphorus than is usually found in the ordinary grades of cast iron because the metal must be capable of flowing readily and filling the mould. It would be rather difficult to use the ordinary casting metal because it would not flow readily into the small spaces left in the sand when the flanges are moulded, but the metal containing phosphorus in larger proportions fills these spaces completely, and makes it possible to obtain cylinder castings with perfectly formed cooling flanges. Some of the cast irons used in cylinder construction also contain some tungsten, and this alloying element produces an iron that has a high degree of resistance to heat.

The common method of finishing cylinders of the simple form, i. e., without a cylinder head is to bore these out with a roughing cut and then to anneal the castings and allow them to age for a time before the finishing processes take place. The reason for the annealing and aging is to remove any internal stresses that may have been left in the cylinder casting when the moulten metal cooled, and usually removing the scale as is done by the roughing cut, permits the cylinders to distort appreciably. If the finishing process is continued right after the rough boring without the annealing, just as soon as the cylinder was put in service it would be apt to distort sufficiently under the high heat to produce some friction between the piston and cylinder walls. In annealing the cylinders, they are placed in a furnace and heated to a higher temperature than will ever be produced by the explosions after they are in service. This tends to not only relieve the strains produced in casting but after the cylinders are cooled they have distorted as much as they ever will. The aging process is a simple one as it consists of allowing the cylinders to remain undisturbed after they cool for several weeks.

There are two methods of finishing the cylinders followed by most engine builders. One of these consists in taking a finishing cut or of removing enough metal from the cylinder bore, so the size is very close to standard, after which the remaining metal is removed by reaming. The other method is to grind out the surplus metal by high speed

emery wheels mounted on a spindle that is adapted to traverse the length of the cylinder. Those who favor reaming contend that the grinding process will deposit small particles of emery in the open pores of the cast iron, and that this material is only dislodged after the engine is placed in service, at which time it will cause trouble by producing scratches on the cylinder walls. Those who favor grinding contend that the reaming process does not produce as true and smooth a bore as grinding, because if a reamer blade strikes a hard spot in the metal of the cylinder wall it will spring away from the hard portion and cut a little deeper than it should in the softer portions opposite. Some makers follow the reaming process with a lapping operation, which is done by revolving the cylinder in a suitable fixture, and at the same time having a dummy piston made of some soft metal, charged with abrasive and oil, reciprocate rapidly up and down in the cylinder while it revolves. Engines that have the cylinders finished by the lapping process do not need to be run in as long on the block as those in which the cylinders are either reamed or ground to a standard size.

Combustion Chamber Design.—One of the important considerations in the design of the internal combustion motor, and one that has material bearing on its efficiency, is the shape of the combustion chamber, and this is especially true of the air-cooled forms of cylinders which operate at considerably higher temperatures than the water-cooled forms. The endeavor is made to use a form of combustion chamber that will provide for the least heat loss, and that will not interfere with a balanced design of a cylinder. Theoretically, any cylinders having pockets at the side to hold the valves are not as desirable as those forms in which the valves are placed directly in the head, and where the cylinder is uniform in diameter at all points. It is contended by designers favoring valve-in-the-head location that the expansion and contraction of the cylinder will be uniform because the metal is evenly distributed whereas on most patterns, having extensions at the side, the irregular placing of the metal will mean that one portion of the cylinder becomes hotter than the other part, and as it will not cool as fast, the cylinder will not expand and contract evenly at all points. The greater the amount of metal to be heated, the more the heat loss and the less efficient the engine. The im-

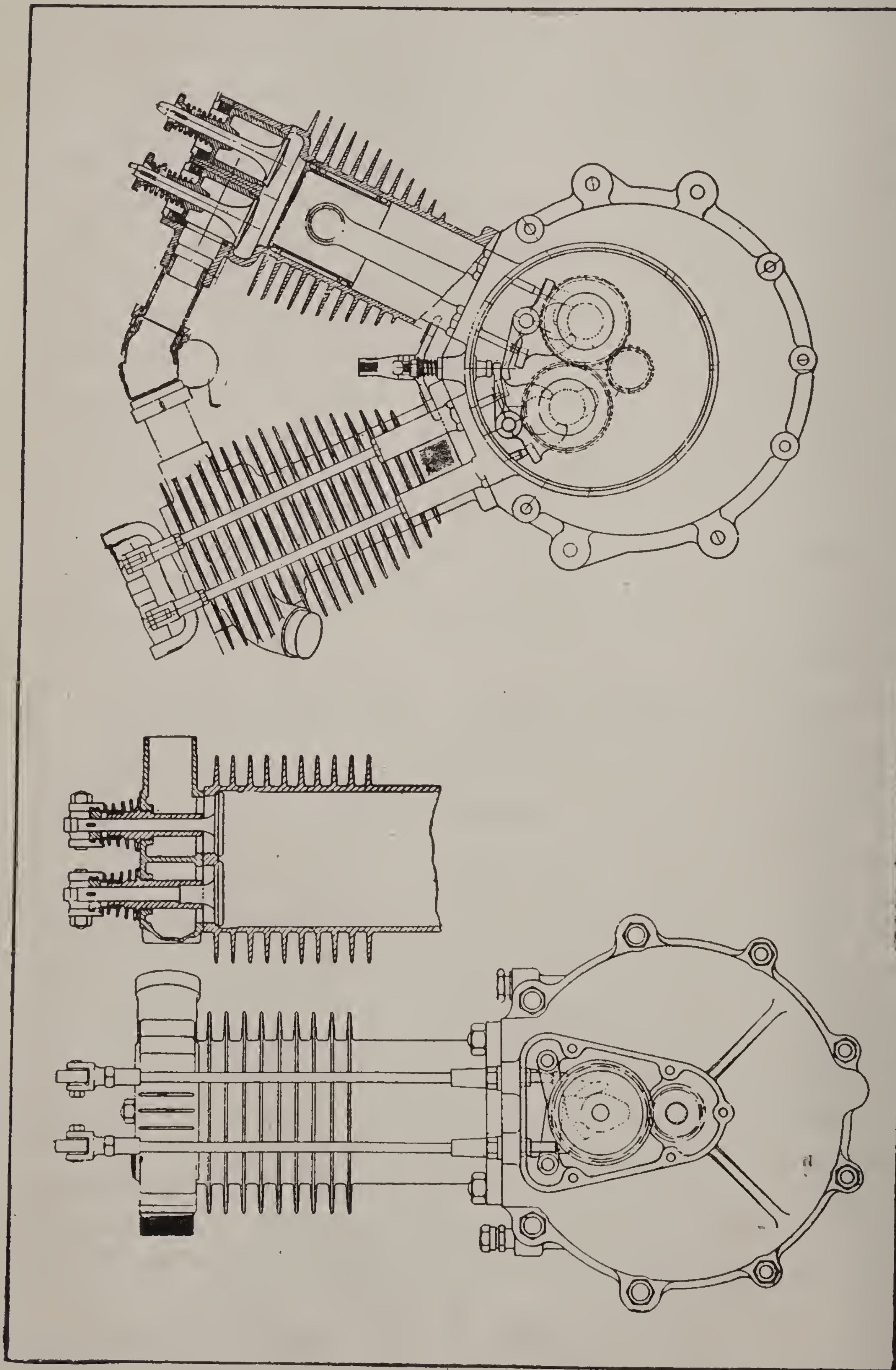


Fig. 80.—Typical Valve-in-the-Head Motors, Showing Methods of Installing the Valves so They Will Open Directly Into the Combustion Chamber.

portant factor that has to do with the form of the combustion chamber used is that of valve placing, and there is considerable diversity in practice as relates to location of the members that control the ingress and egress of gas to or from the cylinders.

Relation of Valve Placing to Engine Efficiency.—The fundamental consideration that determines valve location is that the gas be admitted to the cylinder as quickly as the speed demands, and that after it has been properly compacted and exploded that the inert products of combustion should be exhausted or discharged from the cylinder with as little back pressure as possible. While this is an imperative condition if one is to obtain satisfactory operation from any type of gasoline engine, either air or water-cooled, imperfect operation of the valves will be manifested much sooner in the small high-speed air-cooled motorcycle power plants. For example, if the form of the combustion chamber is such that the entrance of fresh gas is impeded, the cylinder will not fill thoroughly with mixture at high speeds, whereas if the exhaust gas flow is impeded to any extent a part of the burnt gases will be retained in the cylinder, and these will reduce efficiency by diluting the fresh charge and making it slower burning, and thus cause lost power and overheating.

Another factor that has a decided bearing upon the rotative speeds of small internal combustion engines is the sizes of the valves, and some valve locations permit the use of larger valves than do other positions. As will be seen by reference to illustrations, Figs. 80 to 85, inclusive, there are many ways of installing the valves, and that each method outlined must possess some points of merit is best proven by the fact that practically all of the forms illustrated are used by reputable manufacturers of motorcycles.

The valve in the head system, which is shown in two forms at Fig. 80, possesses important advantages from a theoretical point of view, and actual performance has indicated that it is a very desirable form of construction. When the valves are placed directly in the head, the inflow is direct, and the discharge is obtained with minimum back pressure. The inside of the combustion chamber may be machined, making a very good construction for an air-cooled cylinder. The cylinder casting is simple, and large valves may be employed which can be easily removed if either the cage or the removable head con-

struction are used. The machined combustion chamber is advantageous for several reasons, one of the most important of which is that there are no sharp edges or corners to become hot and cause pre-ignition of the charge, and it is also difficult for carbon deposits to lodge on perfectly smooth machined surfaces. The combustion

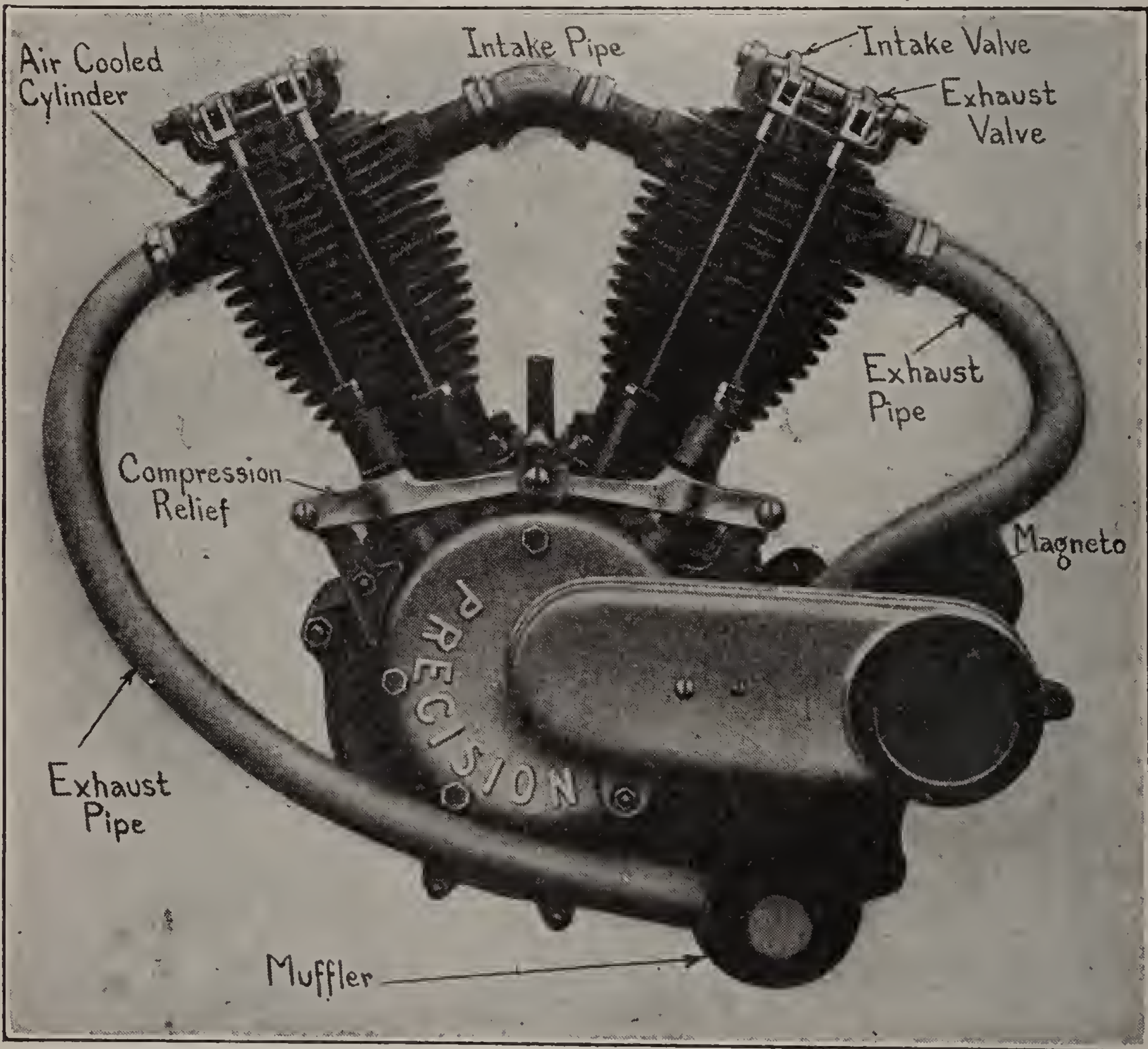


Fig. 81.—The Precision Twin Cylinder Valve-in-the-Head Motorcycle or Cyclecar Power Plant.

chamber is uniform in shape, and expansion will be even when the cylinder is heated.

When the valves are placed in the head there are two main methods of construction followed. In one of these, the head casting is removable, and the valves seat directly in that member. In the other construction, the valves are carried in cages inserted into openings pro-

vided for their reception when the cylinder is a one-piece member. The valve-in-the-head motor shown at Fig. 81 is the same as that outlined in section at Fig. 80, and the method of operating the valves when at the top of the cylinder may be readily understood. The valves are not always placed with the stems vertical, so that they are

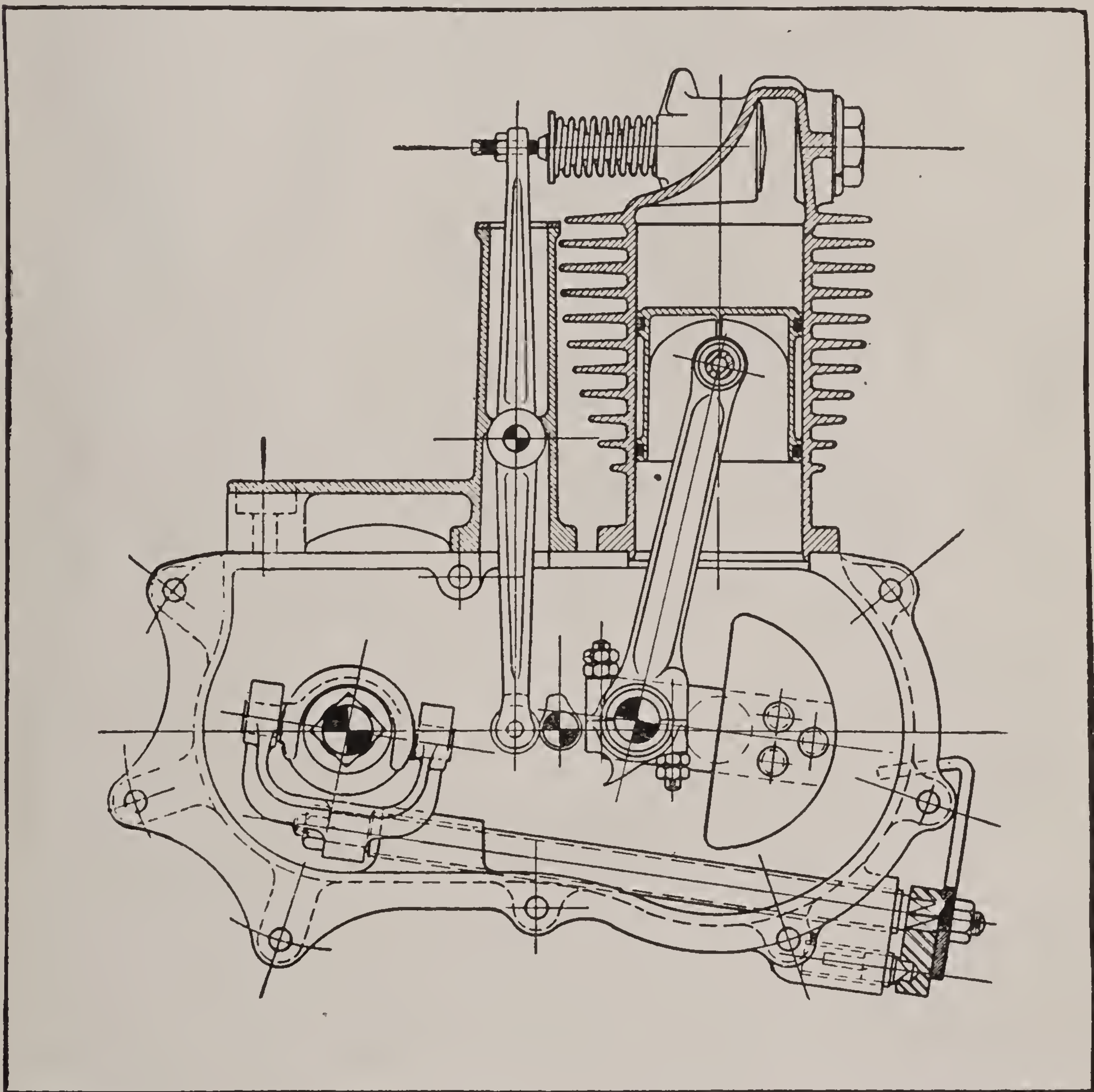


Fig. 82.—Unconventional Arrangement of Valves in the Precision Junior Motorcycle Power Plant.

pushed down by rocker arms when it is desired to admit gas into the cylinder or to open a port for its discharge, as in some cases the valves are placed with their stems horizontal as shown at Figs. 82 and 83. The former shows a light English power plant in which the valves seat directly in the cylinder head. They are actuated by long rocker

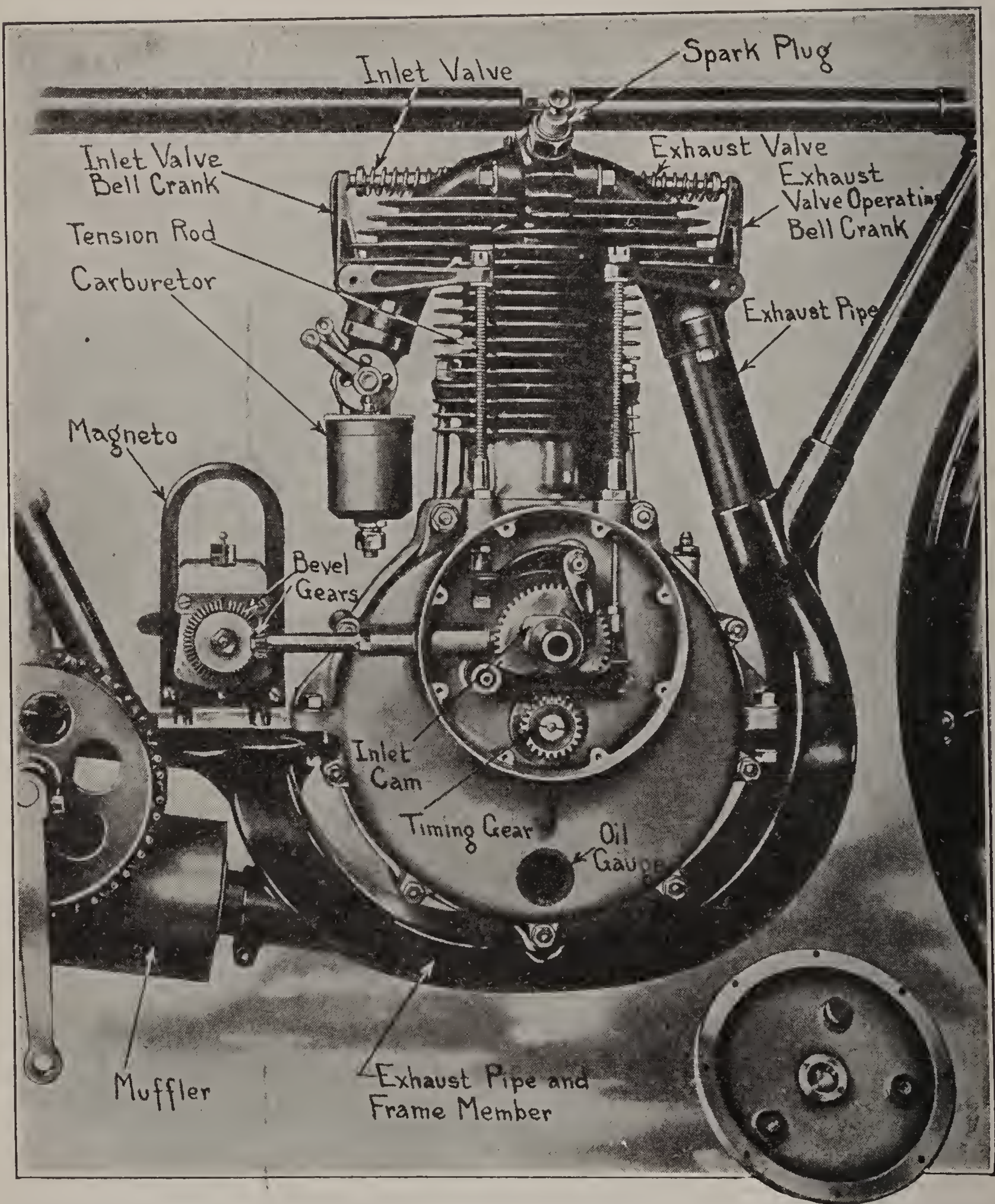


Fig. 83.—An Unconventional American Motorcycle Power Plant of Early Design in Which the Horizontal Valves Open Directly Into a Vertical Combustion Chamber.

arms fulcrumed at approximately their central point, and have a roll at the lower end to follow cam profiles, while an adjustable set screw at the upper end imparts motion to the horizontal valve stem. The valves may be readily exposed for grinding by removing the valve

cap at the front of the cylinder. The valves are placed side by side, and both are mechanically operated.

The peculiar method of valve placing shown at Fig. 83 was used with some degree of success on one of the earlier American motorcycles known as the Royal. In this, the valves were carried in cages that bolted to an extension from the top of the cylinder that formed a narrow combustion chamber. The valves were placed horizontally, and were operated by bell cranks pivoted on the valve cage extension, and these were actuated by tension rods instead of the usual form of compression or push rod. The valves were opened by a downward movement or pull of the rod instead of by an upward motion as is now conventional practice. The engine described proved very satisfactory in practical service, and many machines were made using this unconventional power plant before the manufacture of these machines was discontinued.

The usual arrangement of the valves is as depicted at Figs. 84 and 85. In this system, which is the oldest in use, as it was originated by Daimler, the inlet valve is located directly above the exhaust member, and is usually carried in a valve cage held in place by a suitable dome or other retaining means. The dome on the Indian motor, which is shown at Fig. 85, is secured in place by an ingenious bayonet lock arrangement so it can be easily removed by moving it over from the position shown about half a turn and lifting it out. The form of combustion chamber made possible has considerable merit, especially in air-cooled motors, as the fresh, cool gases from the carburetor strike the exhaust valve head, and have a very beneficial effect as they assist in reducing the temperature and by preventing the valve head from overheating, the valve or its seating is not so apt to warp and pit as would be the case if it were not adequately cooled. The inlet valve may be of either the automatic or mechanically operated type, though, at the present time, practically all inlet valves are actuated by positive mechanical means. The cylinder is an easy form to machine, and the casting, even when the combustion chamber is integral with the cylinder, is not a difficult one to make.

One of the disadvantages of this construction is that if large valves are employed, the pocket must be of corresponding size, and considerable heat loss will result, due to the irregular form of the com-

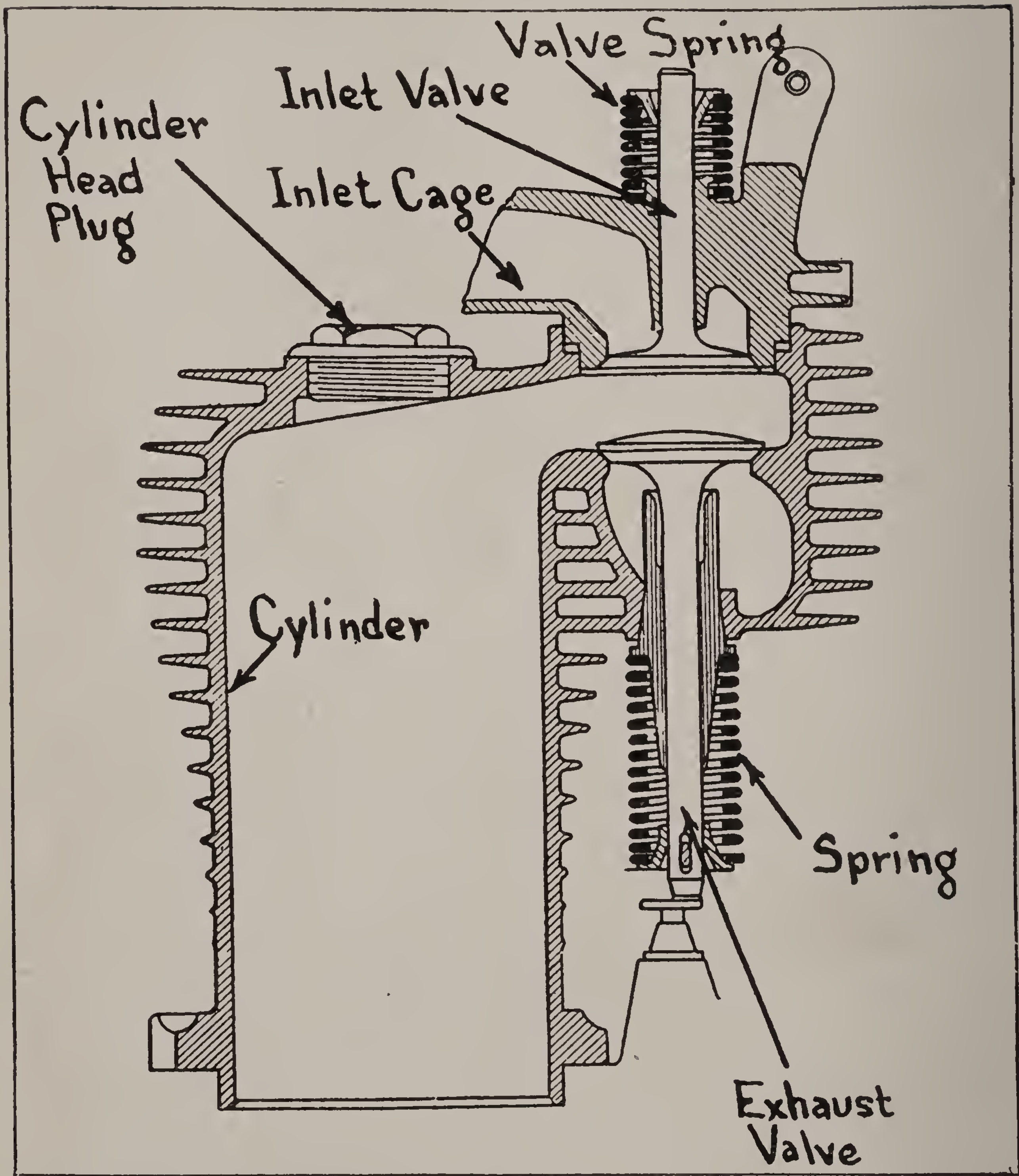


Fig. 84.—One-Piece Motorcycle Cylinder, Showing the Valve Arrangement Generally Employed.

bustion chamber. The gases cannot be discharged as directly as when the valves are placed in the head, as there is a sharp corner that must be turned whether the gas is flowing in or out of the cylinder. This feature is not one that is of sufficient importance to be advanced as a positive disadvantage, because so many of the very efficient motorcycle power plants have the valves arranged in the manner shown

that the practicability of this arrangement cannot be questioned. It is customary, when the valves are arranged in the manner described, to locate the spark plugs in the side of the combustion chamber so the points or electrodes will be swept by the incoming gases. This tends to keep the temperature down and to keep them free of oil to some extent.

The form of cylinder shown at Fig. 88 is known as the L-cylinder, because of its shape. The valves are side by side and are located in a common extension from the combustion chamber, and in multiple cylinder tandem forms, it is possible to operate all valves from a common single cam shaft. The valve chamber is closed by threaded plugs at the top, and the valves may be easily reached by removing these members. A very simple valve-operating system is possible, and the springs and valve adjustments are easily reached when desired. The chief disadvantage advanced against this form of cylinder is that a very large pocket is necessary unless the valves are restricted in size. If considered from a purely theoretical point of view, this form of cylinder has the same disadvantages as the T-head form, in which the valves are placed at opposite sides of the cylinder, each in a separate extension, though to a somewhat lesser degree. The combustion chamber form that is most effective is that in which the valves are placed directly in the head, and next in order comes that shown at Fig. 85, in which the valves are placed one above the other with the extension of just the size necessary for the one valve. In the form in which the valves are placed side by side the efficiency is a little greater than in the T-head form, where the combustion chamber is of a shape that permits of considerable heat loss.

The T-head construction has an important advantage in that large valves can be used, and a better balanced cylinder casting is possible than if the L-head construction is used. There are two valve chambers, usually of equal size, so the expansion is apt to be more uniform when the cylinder is heated than in those constructions having a valve chamber at but one side of the cylinder. Wherever the pocket construction is used, in addition to heat loss and the uneven cylinder expansion, it must be obvious that the passage of the gases will be impeded to some extent. For instance, consider a cylinder of the L form. When the piston goes down on its suction stroke, the

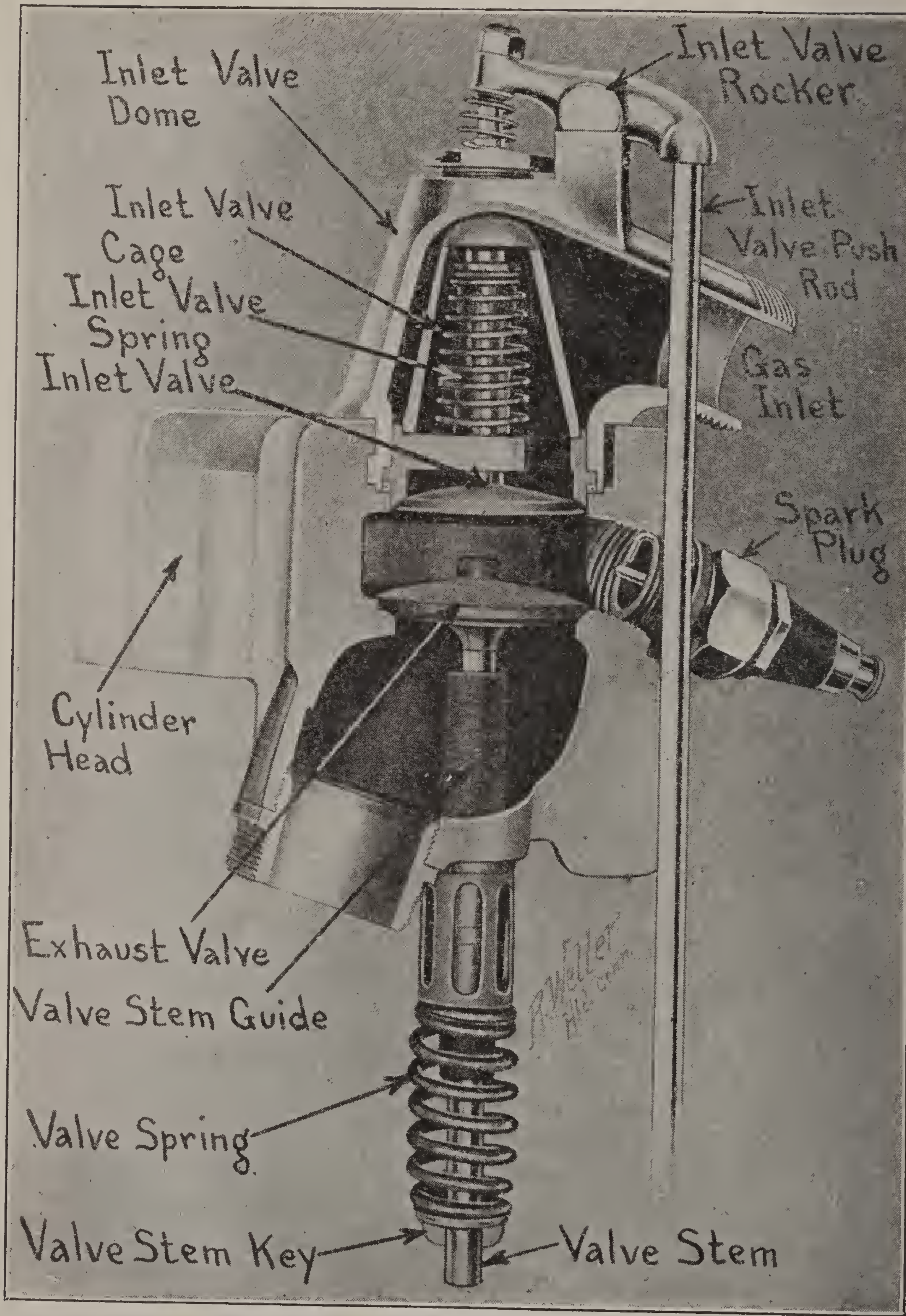


Fig. 85.—Detachable Combustion Head of the Indian Motor With Valve Chamber in Section to Show Arrangement of Intake and Exhaust Valves.

inlet gases rushing in through the open inlet valve will impinge themselves sharply upon the valve cap, and then the direction of flow changes abruptly at a sharp angle to permit the gases to enter the cylinder. The same applies to the exhaust gas, except that the direction of flow is reversed. When the valve-in-the-head type of cylinder is employed the only resistance offered to the passage of the gas is

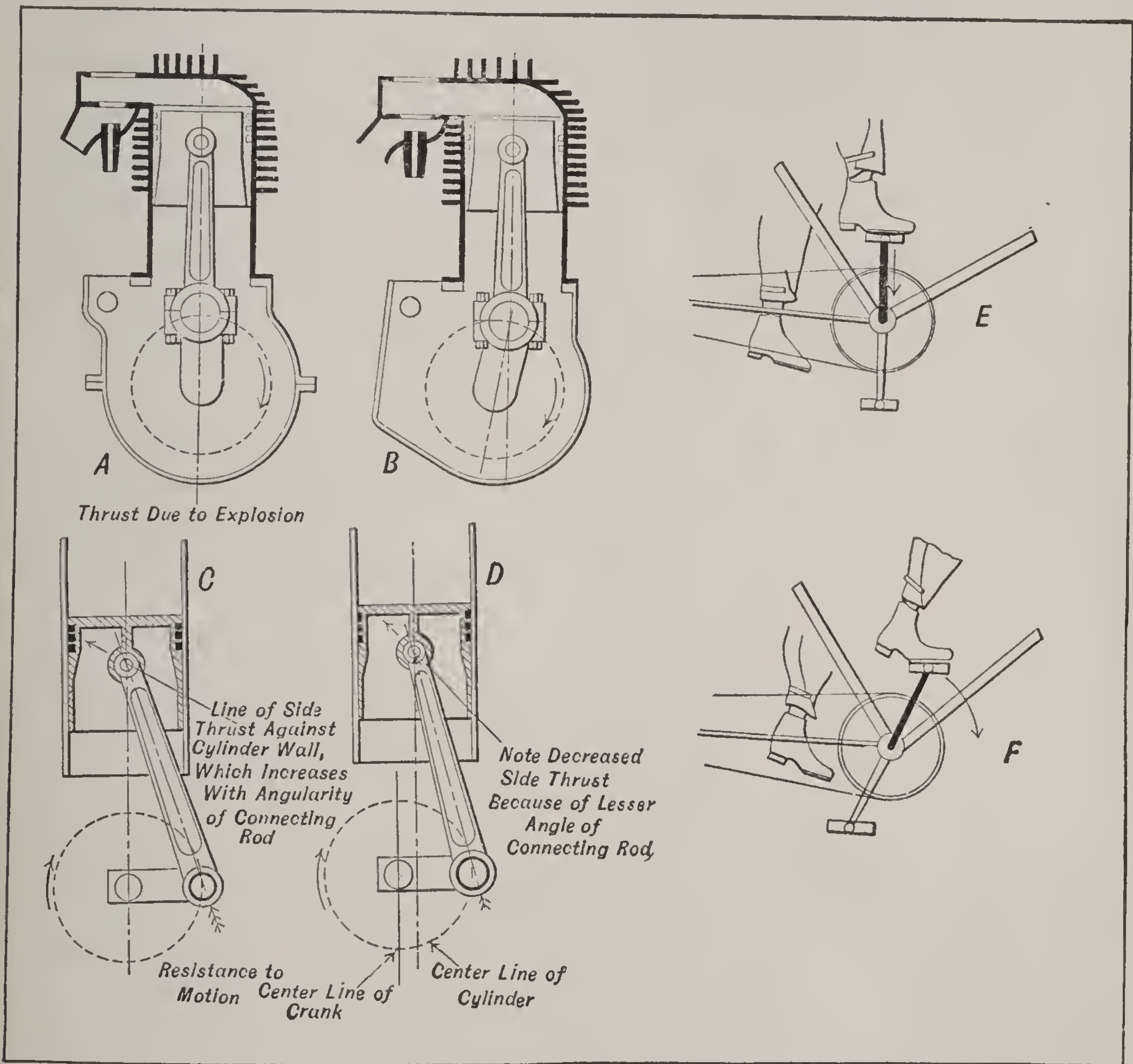


Fig. 86.—Diagrams Illustrating Advantages of Offset Cylinder Construction.

in the manifold, and if these are properly proportioned the velocity of gas flow will not be reduced much. Experience has shown that a valve-in-the-head motor is more flexible and responsive than the other forms, and in most cases it will be somewhat more efficient and deliver more power than others of the L or T form that have the same piston displacement.

Bore and Stroke Ratio.—A question that has created considerable discussion among automobile engineers is the proper relation of the bore to the stroke, and recent developments indicate that long-stroke motors, which are those forms where the piston travel is 1.5 or 1.75 times the diameter of the cylinder bore, have many advantages to commend them. While the long stroke principle is well adapted to motors designed for low and moderate speed, it is not suited as well for the small high-speed motors used as motorcycle power plants. The stroke seldom exceeds the bore by any material amount, and the usual ratio is 1 to 1.25. For example, an engine with a 3.5-inch bore would not be likely to have more than 4-inch stroke. The reason that the length of the stroke or the amount of piston travel does not exceed the diameter of the bore by any great amount is the endeavor to keep within proper limits as regards piston speed.

In an air-cooled motor, the question of lubrication is the main governing factor, which determines the velocity of piston motion, and the greater its speed, the more difficulty there is in securing proper oiling of the reciprocating member. Most automobile engineers endeavor to keep the piston speed to about 1,000 feet per minute, though in motorcycle engines satisfactory service is obtained with piston speeds as high as 1,200 feet per minute in machines built for road work and even higher if the engines are designed with the requirements of racing service in mind.

Let us consider what is meant by piston speed and how this influences the number of revolutions possible. Assume that we have an engine with a stroke of 6 inches, it is evident that during 2 strokes the piston will have covered a distance of 1 foot. As there are 2 strokes per revolution of the fly-wheel or crankshaft, it will be seen that a normal speed of 1,000 revolutions per minute is permissible for an engine with a 6-inch stroke without exceeding the limits established by engineers. If the piston had a stroke of 4 inches, 1,500 revolutions would mean a piston travel of 1,000 feet per minute, and with a 3-inch stroke, the safe speed of 1,000 feet would not be exceeded if the engine crankshaft revolved 2,000 times per minute. There is no arbitrary rule that can be cited as establishing the factor of piston speed or relation of bore to stroke definitely and in races,

engines have been used where the piston speed was over twice that considered good practice.

Influence of Compression on Power Developed.—The relation of compression ratio to the amount of power obtained when the charge of gas is exploded is such that more power is obtained with high compression than where the gas is not compacted to such a degree. With water-cooled engines, such as used in general automobile practice and a few motorcycles, it is possible to use higher compressions which mean a smaller combustion chamber in relation to the volume swept by the piston than is permissible with air-cooled engines. This is because more heat is developed with a high compression prior to ignition and it is possible to compress the gas to a point where the engine would overheat rapidly owing to the limitations of the air-cooling system. An engine with a high compression is not so well adapted for general service as one with a medium compression because the engine will not be as flexible or operate as smoothly under normal service conditions. The general practice in motorcycle engines intended for road use is to use a compression pressure of about 60 pounds gauge indication which means that the gas in the cylinder and combustion chamber is compressed to about one-fourth the volume it occupies before it is compacted. In an air-cooled motor, if the compression pressure exceeds 75 or 80 pounds, the engine will heat up rapidly and the cylinder head will soon become hot enough to fire the gas without the aid of the electric spark. This results in pounding, and while the engine is more powerful than a type with lower compression, it cannot be used for any extended periods without incurring the danger of preignition.

The following table shows the maximum explosion pressure, in pounds per square inch, obtained with various degrees of compression. In this case, the compression ratio means the volume the gas occupies after compression based on an initial pressure of about 15 pounds per square inch, which is that present in the cylinder when the piston reaches the end of its suction stroke, and when the cylinder is full of gas, and, therefore, has the same pressure as the atmosphere. A compression ratio of 3 means about 45 pounds compression. A ratio of 4 about 60 pounds, etc. The actual amount of compression is not the pressure that one would obtain by multiplying the atmospheric pres-

sure directly by the ratio of reduction in volume because compressing the charge increases the temperature, and this in turn produces an increase in pressure so that the actual compression is somewhat higher than would be obtained by a simple calculation. This variation is not sufficiently great however, so that it must be considered at length in a practical discussion; so we will assume, in comparing the results of the table appended, that the compression pressure is that of the atmosphere multiplied by the compression ratio indicated.

MAXIMUM EXPLOSION PRESSURE.

Compression Ratio.	Maximum Explosion Pressure (Pounds per square inch)
3	230
3.2	250
3.4	274
3.6	298
3.8	321
4.0	344
4.2	368
4.4	392
4.6	414
4.8	437
5.0	460

It will be evident that as the compression increases, the amount of pressure obtained when the charge is exploded augments as well, and that if there were no other consideration involved, the engine with the highest compression would give the most power.

Offset Cylinders.—In some constructions, the cylinder is placed on the engine base so its center line is to one side of the center line of the crankshaft, and diagrams are presented at Fig. 86 which make clear the advantages obtained by this method of cylinder placing. The view at A is a section through a simple motor having the conventional cylinder arrangement and the center-lines of both crankshaft and cylinder coincide. The sectional view at B shows the

cylinder placed to one side of center so its center line is distinct from that of the crankshaft and at some distance from it. The amount of offset to be allowed is a point upon which considerable difference of opinion exists, the usual offset being from 15 to 25 per cent. of the stroke.

The advantages of the offset are shown at C and D. If the crankshaft turns in the direction of the arrow, there is a certain resistance to motion proportional to the resistance offered by the load which is always less than the amount of energy exerted by the engine as long as the vehicle is in motion. There are two thrusts acting against the cylinder wall to be considered, one of these due to the expansion of the gas against the piston top and the other being produced by the force that resists the motion of the piston. These thrusts may be represented by arrows, one of which acts directly in a vertical direction on the piston top, the other on a straight line through the center of the connecting rod. Between these two thrusts, a third line may be drawn to represent a resultant force that serves to bring the piston in forcible contact with one side of the cylinder wall. This angular resultant is generally termed "side thrust." In the engine shown at C which is one in which the center line of cylinder and crankshaft coincide, the crankshaft is at 90 degrees or about one-half stroke, and the connecting rod is at approximately 20 degrees angle. A shorter connecting rod would increase the diagonal resultant and side thrust, while a longer one would reduce the angle of the connecting rod, and correspondingly diminish the side thrust. With an offset construction depicted at D, it will be noted that the same connecting rod length as shown at C, and with the crankshaft in the same position, the connecting rod angle is but 14 degrees, and the side thrust is reduced proportionately.

Another important advantage is that greater efficiency is obtained from the explosion with an offset crankshaft, because the crank-pin is already inclined when the piston is at top center, and all of the energy imparted to the piston by the explosion may be utilized directly and will produce a useful turning effort. With the cylinder placed directly on a line with the crankshaft, as shown at A, some of the force produced by the explosion will be exerted in a straight line, and until the crank moves, the pressure that might be employed in

obtaining useful turning effort is wasted by producing a direct pressure upon the lower half of the main bearing and the upper half of the crank-pin bushing. If one will compare the illustrations at E and F, this important advantage offered by the offset construction may be readily understood. This shows a bicycle crank hanger, and it is apparent that the effort of the rider is not as well applied when the crank is at position E as when it is at position F. In fact, practically all riders instinctively place the pedal as shown at F when starting out, because it is much easier to start the bicycle under these conditions than when the crank is straight up and down. Apparently, position E corresponds to the construction shown at A where the cylinder and crankshaft centers coincide, while that at F is comparable to the conditions present when an offset cylinder is employed.

It is advanced by those who do not favor the offset cylinder placing that while side thrust is diminished on the explosion stroke it becomes greater than in the other construction on the compression and exhaust strokes. This is true, but it would seem to the writer that it is more desirable to reduce side thrust under conditions where the maximum pressure is exerted against the piston top, as obtains during the explosion stroke, even if a little sacrifice is made on the upstroke against the much lighter pressures that are present on the compression or exhaust stroke.

Automatic and Mechanical Valves.—The first motorcycle engines evolved, as was also true of the early forms of automobile motors, had but one of the valves in each cylinder operated by mechanical means. The inlet valves could be controlled by the suction of the piston as it descended on its inlet stroke, because the difference in pressure between the cylinder interior and that of the outside air was such that a partial vacuum existed in the cylinder, and as the valve head had more pressure on its upper side than on that adjacent to the combustion chamber it would, of course, open automatically. The spring on the valve stem needed only to be heavy enough to return the valve to its seat at the end of the inlet stroke. When the pressures above and below the valve heads had become equalized through the cylinder filling with fresh gas, it was approximately at atmospheric pressure at the end of the stroke. When the piston started to go up on the compression stroke, the pressure of the gases

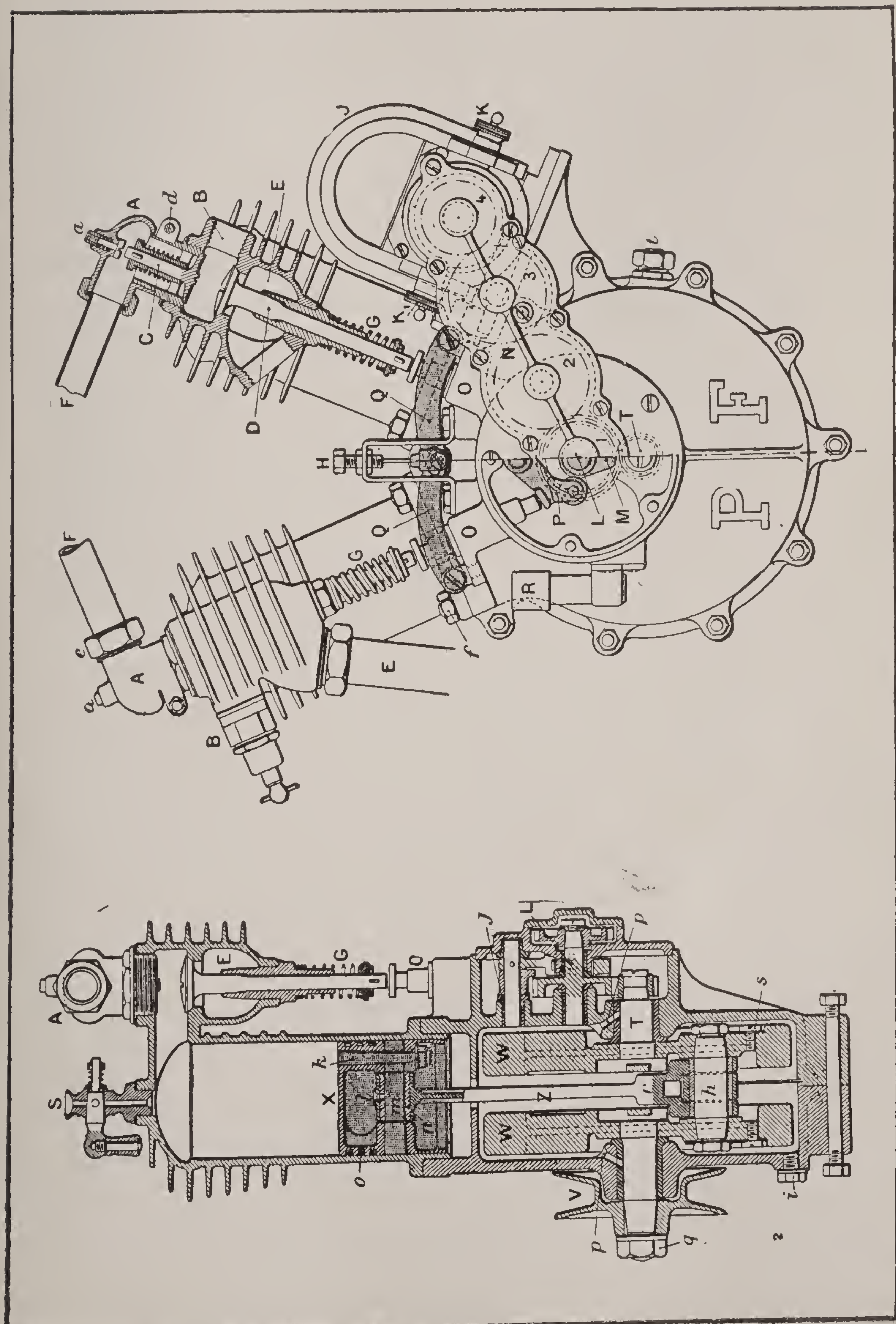


Fig. 87.—Sectional Views of Peugeot Motor, Showing Automatic Inlet Valves.

increased from that of the atmosphere to three and five times this value when the piston had reached the end of its upward movement. This compressed gas and the explosion that followed as well as the pressure in the cylinder during the exhaust stroke were always greater than that of the atmosphere, so the inlet valves remained seated, and only opened when there was a partial vacuum in the cylinder.

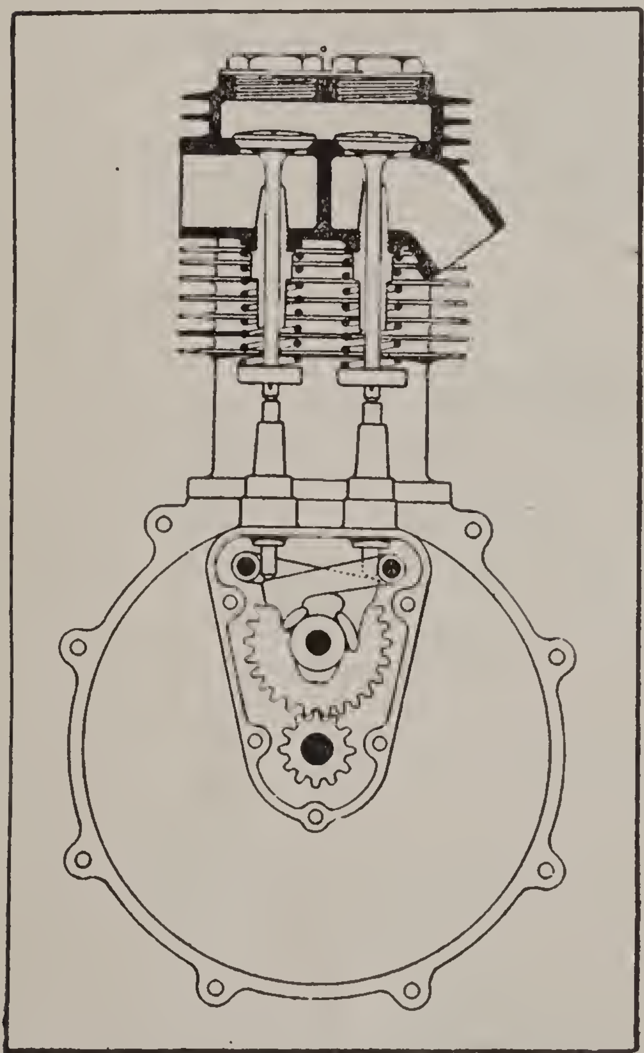


Fig. 88.—Sectional View of L Head Cylinder, Showing Arrangement of Valves When Duplicate Members are Used for Inlet and Exhaust Port Control.

The automatic valve had an important advantage and that was its simplicity, as it did not require any external operating mechanism. At the other hand, a motor fitted with automatic inlet valves was not as satisfactory, after it had been in service for a time, as the form in which the inlets were actuated mechanically. Automatic valves were apt to flutter at low engine speeds, and were not only noisy but also prevented drawing in a full charge of gas into the cylinders. Accumulations of congealed oil or carbon between the valve head and seat would tend to make these members stick, which would prevent prompt starting as well as making the valve late in opening. The light springs that were employed to reseat the valves did not have pressure enough to crush any small particles of carbon that lodged between the valve head and its seat, and, as a result, the automatic valve was apt to leak on the slightest provocation. On twin-cylinder engines used for motorcycles or on the four-cylinder types adapted for automobiles, the use of automatic valves did not conduce to smooth running because the only way of insuring that each cylinder

would receive the same amount of gas was to carefully go over the inlet valves periodically to see that the tension of all the springs was the same; that each valve opened the same amount, and that all were properly cleaned. If one cylinder was lubricated more than the others, the valve in that member was apt to stick while the others would function properly. There was no uncertainty regarding exhaust valve operation because these members have, of necessity, always been actuated mechanically, so after rather unsatisfactory experiences with the automatic inlet valve, motorcycle engine designers decided to operate both valves mechanically.

The mechanical valve is positive in action, the spring used to return it to its seat can be made strong enough so that this function is performed correctly several thousand times per minute, and the valve is not susceptible to sticking owing to accumulations of oil or to remain open either partially or completely because of the interposition of some minute piece of foreign matter between the valve head and its seating. A typical motorcycle power plant of the twin-cylinder form, in which automatic inlet valves are employed, is depicted at Fig. 87. Attention is called to the inlet valve depressors mounted at the top of the inlet valve cages A. These were used to open the valves when starting the motor to make sure that they were free, and not stuck to the seat. The sectional view of the valve chamber depicted at Fig. 88 shows one application of mechanical valves, and in this form it will be apparent that the valves are duplicates, which means that the intake and exhaust valves are interchangeable, and only one spare valve need be carried as a replacement.

Valve Design and Construction.—One of the most important considerations in valve design is to have these of ample size, and many factors are to be considered before the size can be determined. Among these may be stated the location in the cylinder, the method of operation, the material employed, the degree of lift or free opening desired, the speed of rotation of the engine, and the method of cooling the engine cylinder. It will be apparent from our review of the various possible valve locations that if these members are placed directly in the cylinder head, we are not only able to obtain an ideal combustion chamber form but we can also use valves of fairly large size. The method of operation also has some bearing on the size of

the valves. For example, when automatic inlet valves were used, it was the general practice to obtain the required area of valve opening by using valves of large diameter, but with less lift or movement than is ordinarily allowed for mechanical valves. For this reason, automatic valves were 15 to 20 per cent. larger in diameter than mechanically operated members. When both valves are mechanically operated,

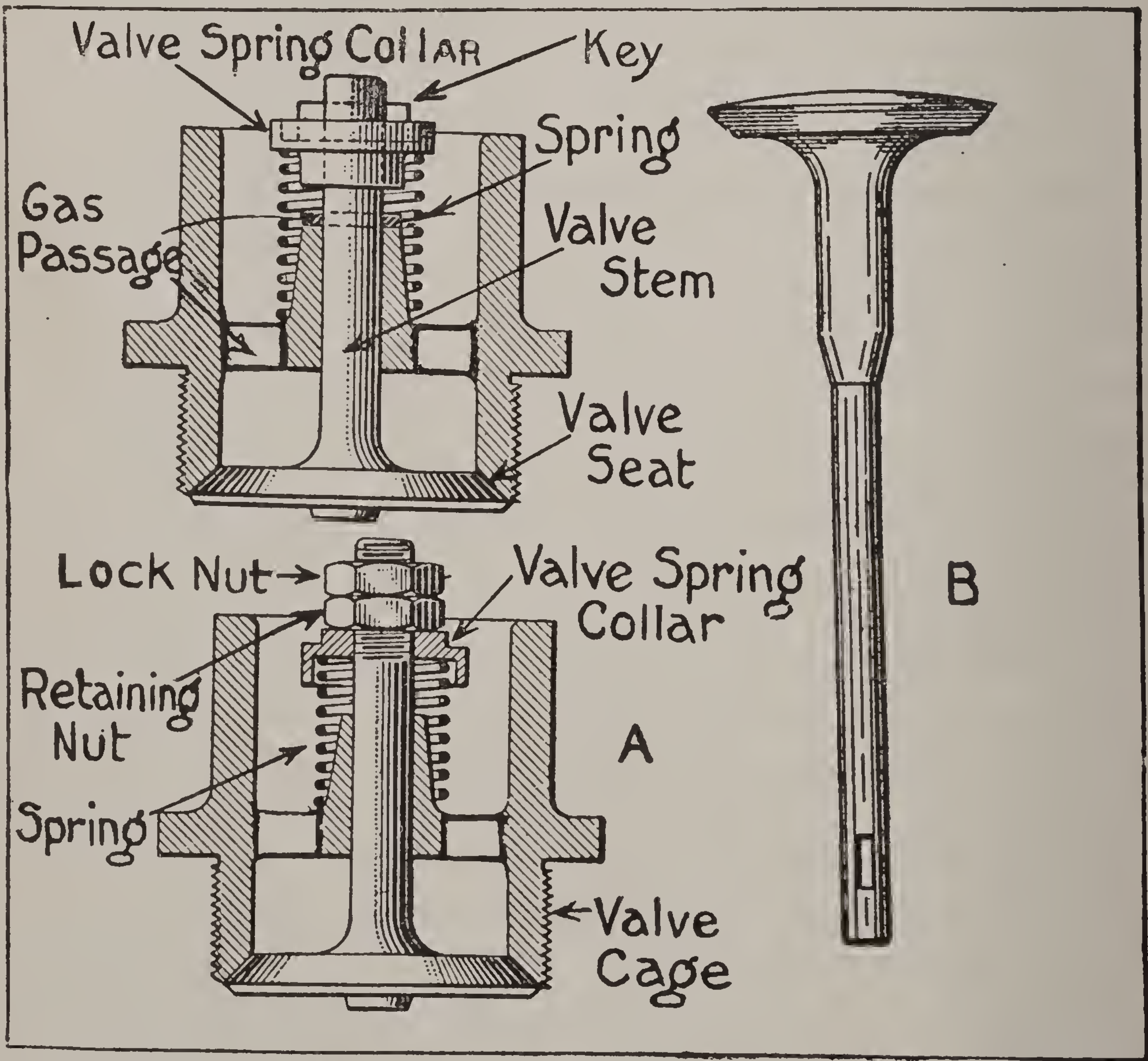


Fig. 89.—Typical Motorcycle Valves. A—Automatic Inlet Valves. B—Usual Construction of Exhaust Valves.

it is an advantage of some moment if they are made of the same size and interchangeable, as this not only greatly simplifies manufacture but is appreciated equally well by the rider if replacements are necessary.

The relation of the valve diameter to the cylinder bore is one upon which considerable difference of opinion exists. The writer has al-

ways been of the opinion that, in air-cooled engines designed for high speed, the valves should be nearly half the diameter of the bore in width, whereas others do not favor diameters in excess of one-third the bore. The larger the area of the valve the less lift required, and this is an important factor where extreme speed is desired, because the valve is more silent in operation, and there is less wear on the parts. A valve with a small lift can be opened to its maximum point by a cam with a low profile, whereas one with a small diameter and requiring greater lift will, of course, require a higher cam that will be somewhat more abrupt in action. A large valve is more subject to warping than one of lesser diameter, and this is a factor that must be considered in connection with the design of exhaust valve. The exhaust valve becomes very hot, especially if the engine is run with a rich mixture and a retarded spark, and it is necessary to make these of materials that are not apt to be affected by heat as well as proportion them so the diameter and distribution of metal around the head will tend to prevent deformation under heating.

The mushroom or poppet valve has become generally accepted in motorcycle practice, though in automobile engineering considerable attention is being paid to development of various types of sleeve, sliding ring, reciprocating piston or rotary forms of valves. The flat seat valve is seldom used in motorcycle practice, though it has been applied to some extent on automobile engines. The usual construction is to use types in which the face of the valve is beveled to fit an angular seating. This form has important advantages, one being that the wedging action of the valve head in its seating not only tends to make a tighter seat but that it is drawn in place positively by the spring pressure. Even if the valve stem guide is worn appreciably the valve will center itself when the beveled head seats. The method of valve construction generally employed is to make that member in one piece, though formerly the head was sometimes made of one substance such as cast iron and riveted onto another material, such as a steel stem. These valves did not prove satisfactory owing to difficulty of keeping the head tight on the stem, as the constant hammering action of the valve head against the seat in combination with the heat caused internal stresses that produced distortion and loosening of the head relative to stem.

At the present time valves are generally machined from forgings of alloy steel and are made in one piece, though valves in which a nickel steel head is electrically welded to a carbon steel stem have received some application. For high-speed air-cooled engines a new tungsten alloy steel has been adopted to some extent. While nickel steel valves have much higher resistance to heat than the ordinary grades of steel or cast iron, the tungsten alloy is unquestionably superior. Tungsten is extensively used in making high-speed steels for lathe tools, and in this service a tungsten alloy metal will retain its cutting edge even when brought to a red heat by the combination of heavy cuts and high speed. These qualities make this alloy especially well suited to air-cooled engine service, and it is contended that a properly treated tungsten valve will retain its toughness and resistance to deformation at temperatures over 500 degrees higher than those ordinarily present in motor cylinders.

The two forms of valves ordinarily used are shown at Fig. 89. The two at the left of the illustration are inlet valves, while that at the right is an exhaust-port controlling member. Inlet valves are usually made lighter than the exhaust, especially if of the automatic form, and the sections can be thinner because the inlet valve is kept much cooler by the flow of the comparatively cool gas, whereas the exhaust valves are subjected to intense heat when the inert products of combustion are discharged as a flaming gas around them. It is good practice, even on inlet valves, to have a large fillet between the valve head and stem because this strengthens the stem at its weakest point, and prevents distortion of the head as well as preserving its proper alignment with the stem.

The two common methods of holding the valve-spring collar in place are depicted. In the upper view, the valve stem is slotted, and a key is passed through it which is prevented from moving sideways by the chambered head of the valve-spring collar. As that member is always pressed securely against the key by the valve spring, the key must stay in place as long as the spring performs its functions. The collar of the valve in the lower portion of the illustration is held in place by a nut and lock nut which fit the threaded end of the valve stem.

The exhaust valve, which is shown at the right of the illustration,

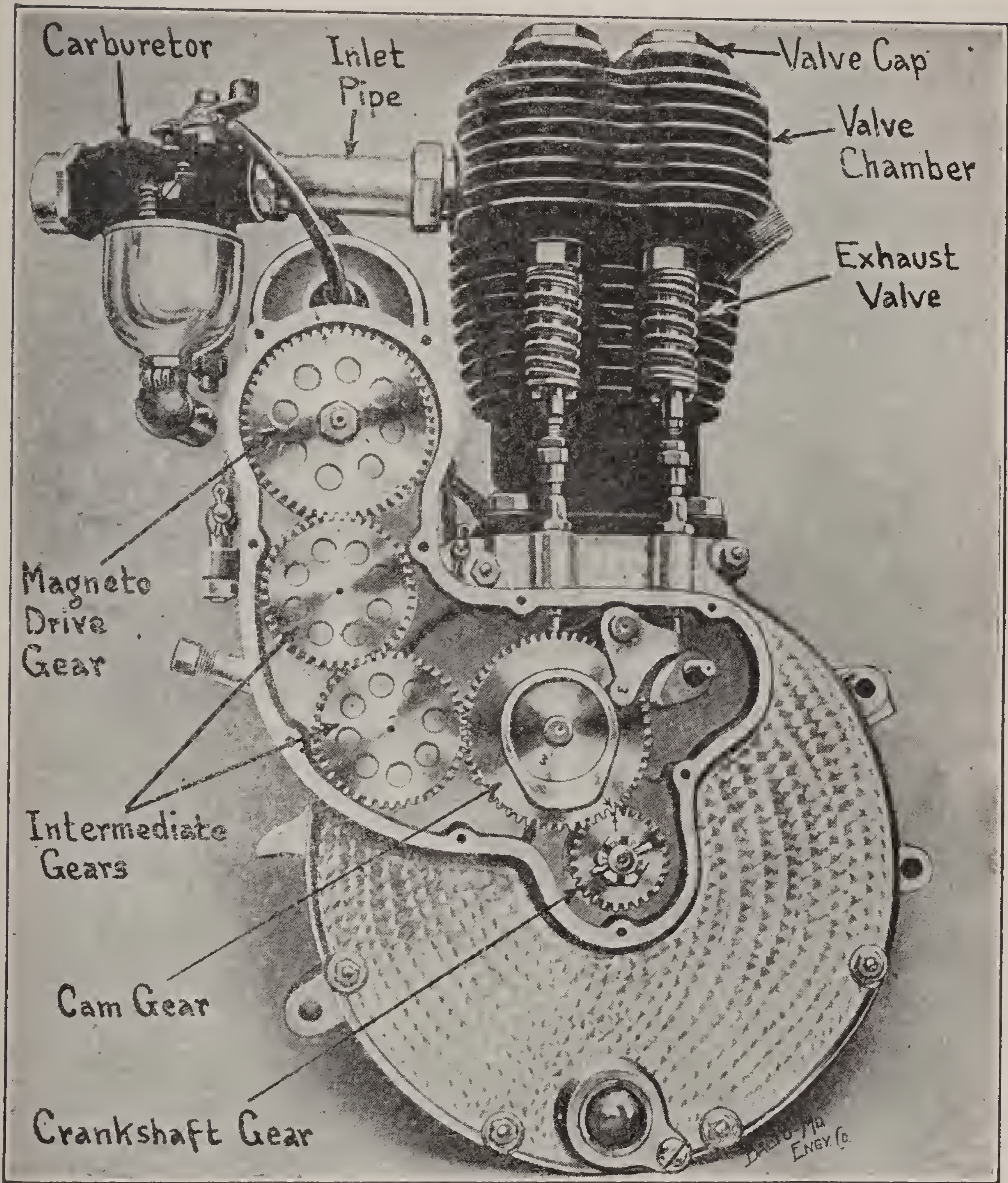


Fig. 90.—View of Reading-Standard Single Cylinder Motor With Timing Gear Case Cover Removed to Show Valve Operating Mechanism.

is an example of excellent valve design. The head is domed, which is preferable to the perfectly flat form, and it is also smooth and without the slotted boss shown on the inlet valves in the same illustration. The slotted boss is necessary on a thin valve head, because it is by inserting a screw driver in this that the valves are turned for grinding.

If a slot was cut directly in a light valve head, it might weaken the construction to some extent. With the domed head, it is a simple matter to cut a screw-driver slot in the arched portion without weakening the head construction. The exhaust valve outlined is a well-proportioned one-piece valve, as there are no sharp corners to become heated, the head is of such shape that it will not warp, and the enlargement of the valve stem near the head not only has a tendency to deflect gases flowing in or out of the cylinder but also strengthens the stem at a point that is normally weak. As the exhaust gas strikes the valve stem immediately below the head when that member is open, and as considerable heat is present that tends to scale and burn away the valve stem, especially if ordinary carbon steel is used, the extra metal is of great value.

How Valves are Operated.—The method of operating the valves of a motorcycle engine is determined by their location, and the general arrangement of the cams employed to raise or depress the valves, as the case may be. When the valves are placed side by side in the cylinder head, as shown at Fig. 90, it is possible to operate them by very simple means as all that is needed is some form of push rod or plunger arrangement supported by suitable guides that will be lifted by small levers riding on the cams, and in turn raise the valve stems against which they bear.

The operation of the cam is not difficult to understand, as most cams consist essentially of a circle having a raised point at one portion of its outer circumference. All portions of the circle are, of course, the same radius from the center except at the point raised to form the cam. As long as the cam rider or follower rests on the circular portion, it will not move, because the point against which it bears on the cam surface is always the same distance from the cam center. When the raised portion of the cam comes in contact with the lever, it will cause that member to move, and this movement may be made to occur at any portion of the crankshaft or piston travel, or exactly when it is needed. The height of the raised portion is one of the contributing factors that determine the amount of valve opening, the others being the proportions or leverage of the cam riders and the adjustment of the valve plungers.

In motorcycle engines, it is now common practice to make the cams

integral with the gear driving them. This gear is always driven at half crankshaft speed, and very often it is one of the members that drives the gear train that produces motion of the magneto armature.

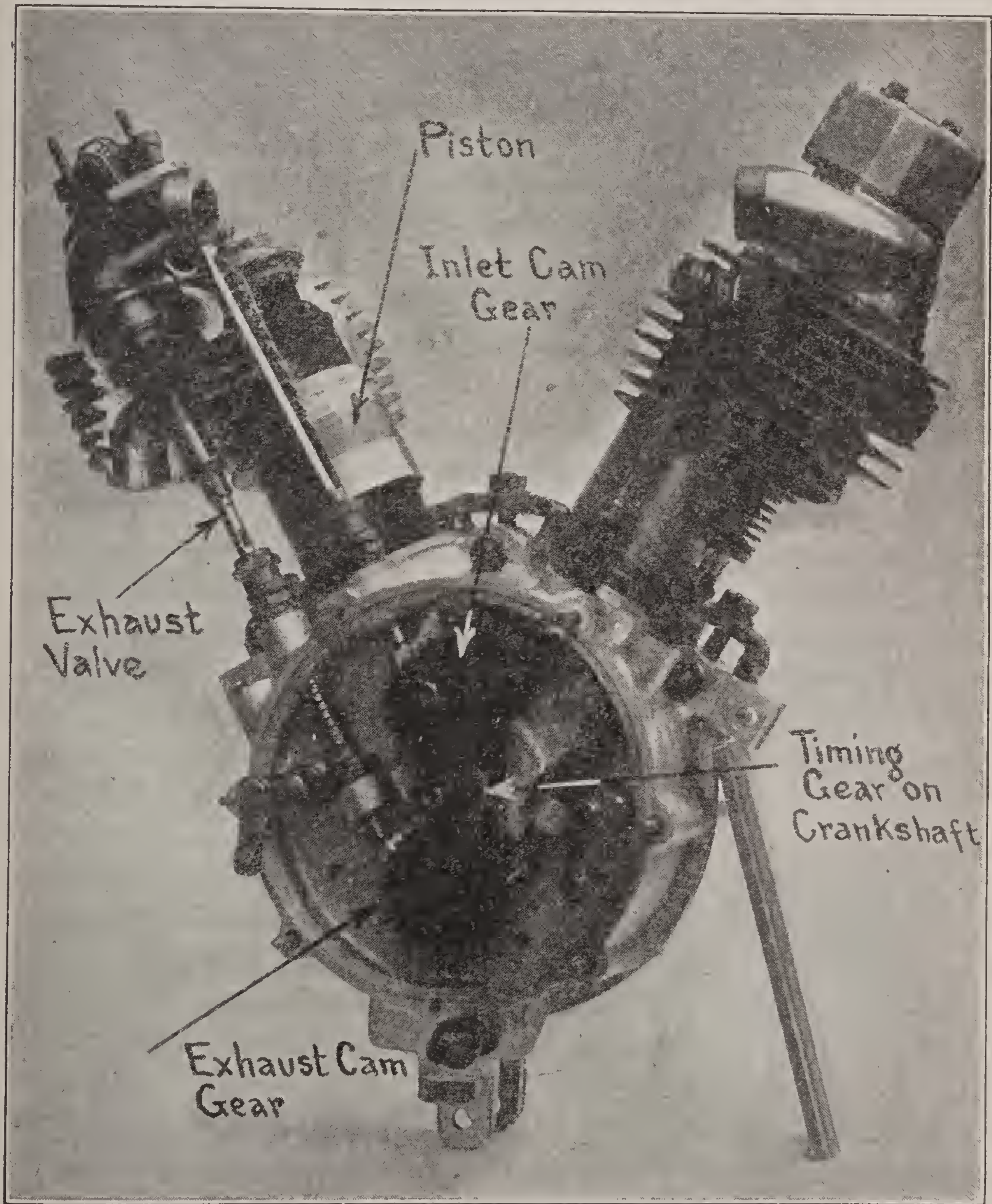


Fig. 91.—Part Sectional View of the Royal Enfield (English) Twin Motor, Showing Application of Two Separate Cam Gears, One for the Inlet Valves, the Lower One for Operating the Exhaust Members.

Sometimes two separate cams are used, each driven by its own gear. An example of this construction is outlined at Fig. 91. In this, the inlet cam and mechanism employed in actuating the inlet valves is mounted above the timing gear on the crankshaft while the exhaust cam and its driving gear is mounted below it. On the multipe-cylinder engines, of which the form shown at Fig. 92 is an example, cylinders of the T-head type are used. In this case, the inlet valve is mounted at one side of the cylinder and the exhaust valves are mounted on the other side. This means that each set of valves must have an independent cam-shaft driven from a common crankshaft gear, and that one cam must be provided on each of these shafts for each valve to be operated. In engines of this type, the valve-operating mechanism is much more direct than in other forms where there may be several cam riders interposed between the cam and the valve stem in addition to the usual valve-operating push rod. In the cylinder, depicted at Fig. 92, the valve-operating push rod is lifted directly by the cam without the interposition of any auxiliary levers, as a roll at the lower end of the tappet rides on the cam and, of course, follows the contour very accurately. This type of construction is much more common in automobile practice than it is on motorcycle engines, because the high-speed power plants used in the latter form of vehicle demand an entirely different treatment as far as the method of valve operation is concerned than do the slower-acting automobile motors.

For instance, where the tappet rod is actuated directly from the cam, there is a certain amount of side thrust present between the tappet and its guide all the time that the tappet roller is being raised by the incline on the cam profile. At high speeds, this thrust action is very noticeable and, as it contributes to wear, high-speed engines soon become noisy if the direct system of valve operation is employed. When a lever or cam follower is interposed between the cam and the valve stem, that member will be subjected to thrust instead of the valve-operating plunger. As an example of the direct method of valve operation, the cross-sectional view at Fig. 92 is excellent, and the two forms of operating the valves that are commonly used may be clearly understood by referring to Fig. 93 where they are well defined. The exhaust valve is operated directly by means of a plunger which bears upon a cam rider which is lifted by a suitable member on the cam-

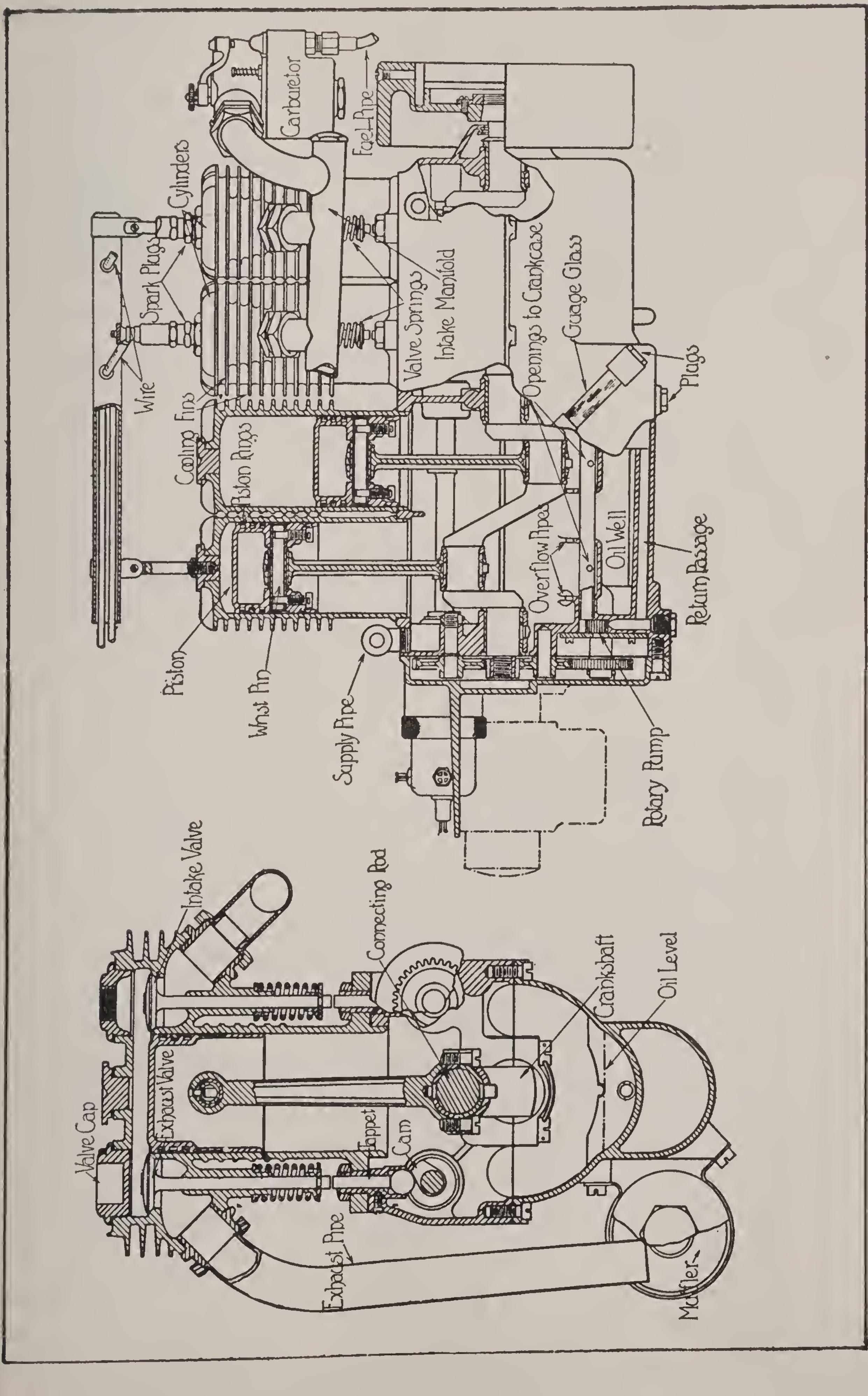


Fig. 92.—Sectional Views Showing Construction of the Pierce Four Cylinder Motorcycle Power Plant in Which Independent Cam Shafts are Employed to Operate the Valves.

shaft below it. The upward movement of the valve-operating plunger results in a direct corresponding motion of the valve, which, of course, must be raised from its seat in order to permit the gas to flow through the exhaust port. The inlet valve, which must be depressed to open, works in a direction opposite to that of the valve plunger movement. While the valve plunger is being raised, the inlet valve stem must be depressed. This is easily accomplished by the use of a rocker arm or simple lever fulcrumed approximately at its center, and having one portion bearing against the valve stem while the other is in contact with a tappet rod extending from the valve-operating plunger. As will be evident, an upward movement of one end of the lever will result in a corresponding movement in the other direction at the other end.

When valves are placed directly in the head, both members are actuated by rocker arms and tappet rods. The view of the valve-operating mechanism at Fig. 94 shows a rather unconventional system in which face cams are used to operate the bell cranks, which, in turn, raise the valves. The usual form of cam has the raised portion on its outer periphery instead of on the face. When face cams are used, considerable end thrust is present on the cam-shaft; and in the engine shown, all end movement of the cam-shaft, due to the side thrust of the spiral gears employed in driving the cam-shaft or magneto or the side thrust against the cams, caused by the valve springs, is taken by a pair of ball-thrust washers which always keep the cam-shaft in perfect alignment, and which prevent any friction because of this side thrust. Plain thrust bearings in the form of hardened steel or fiber washers have been tried at similar points, but these have not proven satisfactory, because too much friction was present between the plain bearing faces at high engine speeds, especially where lubrication was not always adequate. The use of thrust bearings of the anti-friction type means that the cam-shaft will operate for extended periods without any perceptible bearing looseness. With the old forms of plain bearings, when these wore there was considerable end movement possible in the cam-shaft, and considerable strain was imposed on the driving gears and valve-actuating mechanism. The use of ball bearings has entirely cured any trouble due to side movement of the shaft. This motion not only produced considerable noise by

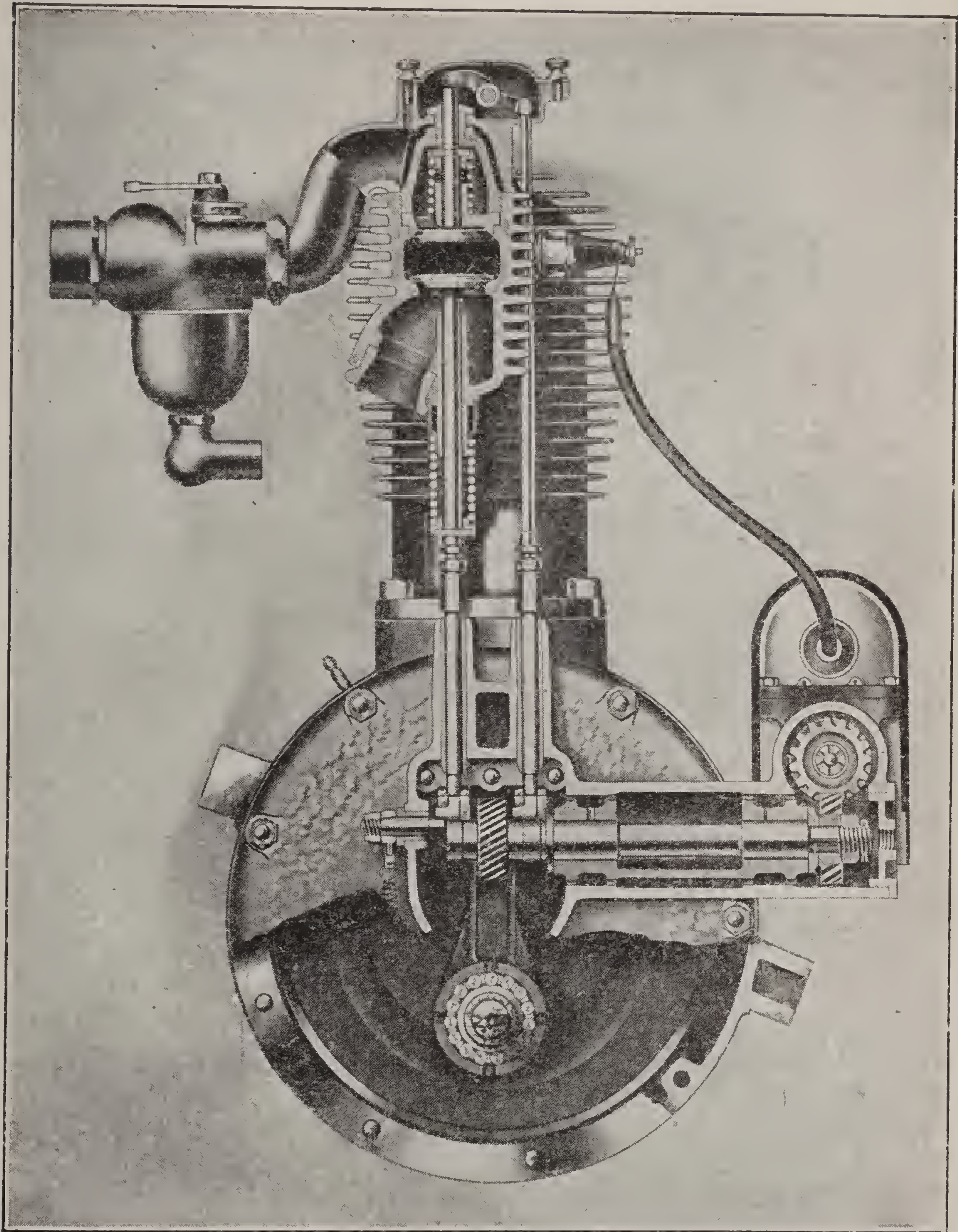


Fig. 93.—Valve Operating System and Magneto Drive of the De Luxe Single Cylinder Motorcycle Engine. Note Also Roller Bearings in Connecting Rod Big End.

permitting the gears to grind, due to poor alignment, and also promoted a metallic knock due to side slap of the cam-shaft, but it also interfered with engine efficiency by altering the valve timing.

The complete valve-operating mechanism used in the Indian motor is shown at Fig. 95, while the method of relieving the compression to permit of prompt starting is clearly outlined at Fig. 96. The inlet

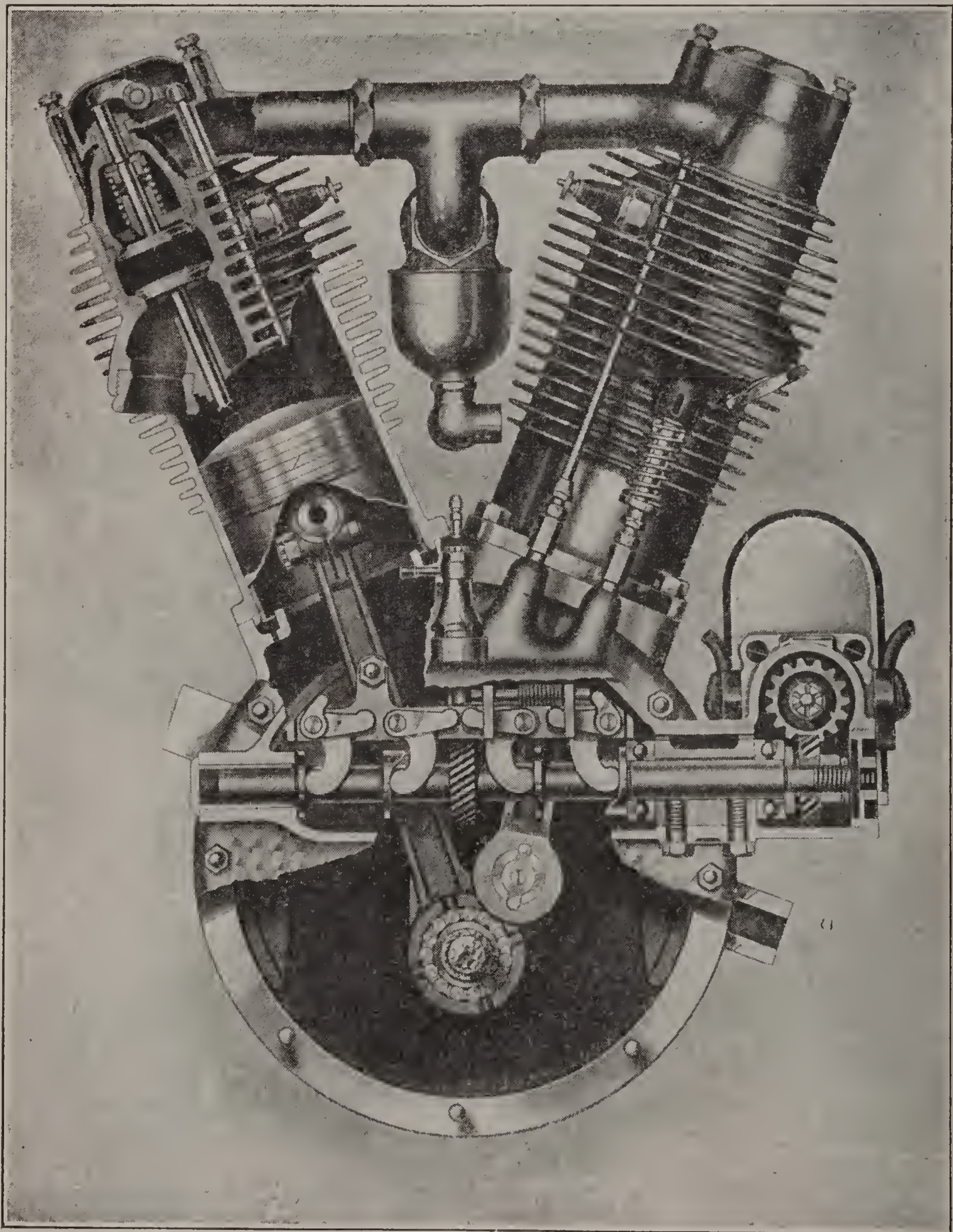


Fig. 94.—Valve Operating Arrangement of the De Luxe Twin Cylinder Motor.

and exhaust cams are integral and are operated by a common cam-shaft. The inlet cam followers are in the form of simple forged bell cranks which bear against the inlet valve lift lever in the manner indicated. A motion of the lower end of the bell crank will be transmitted to the inlet valve lift lever which bears against it. It is claimed for this valve-operating mechanism that the action is quiet at the highest engine speeds, that the system is positive in action, and that it is not subject to rapid depreciation. All of the bell cranks and valve lift levers are of hardened steel, and the entire mechanism is

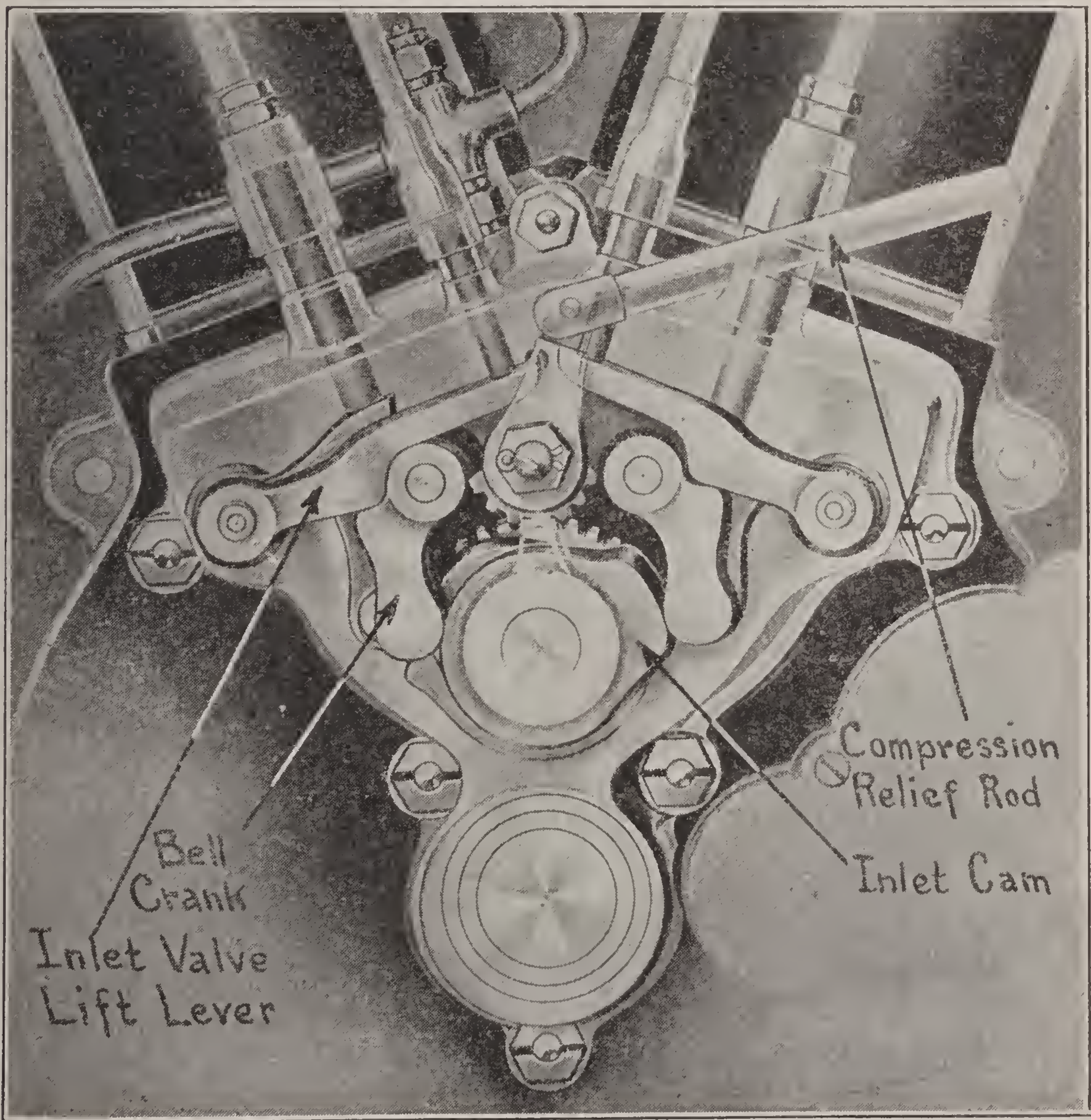


Fig. 95.—Valve Operating Mechanism of the Indian Twin Cylinder Motor.

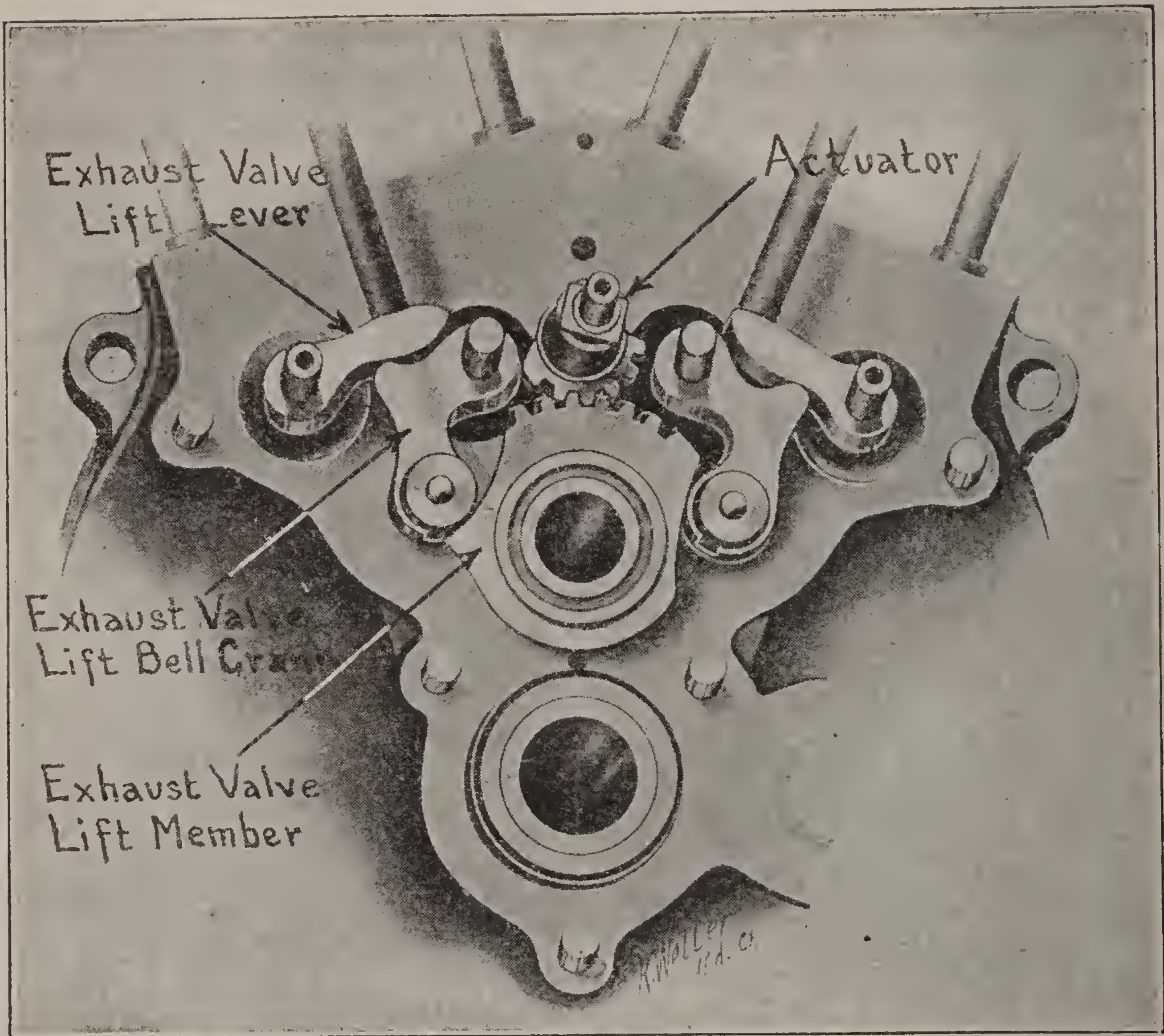


Fig. 96.—Method of Raising Exhaust Valves to Relieve Compression in Cylinders Employed on Indian Twin Motors.

well encased so that it will operate in oil and at the same time be kept clean and free from dirt.

In order to promote easy starting in motorcycle engines, it is customary to provide some system of relieving the compression in the cylinders so the engine may be turned over with minimum exertion on the part of the rider. This is generally accomplished by partially raising the exhaust valves by an auxiliary actuater controlled by hand and independent of the usual exhaust cam. The system used on the Indian motor and shown at Fig. 96 is not only simple, but it is effective and positive as well. A thin double cam member having a series of teeth in the upper portion is placed between the two exhaust valve lift bell cranks. This may be rocked by a toothed segment connected

to the grip on the handle bar. When the double cam is rocked, it will raise the exhaust valve lift bell crank regardless of the exhaust cam position, and these members, in turn, will raise the exhaust valve by the short exhaust valve lift levers they bear against.

The views at Fig. 97 show a simple and effective valve-operating mechanism used on the Precision engines, which are of English design. Both of the mechanisms described are employed on single-cylinder engines. The view at Fig. 97, A, is of the gears assembled on the cam case, and it will be apparent that the engine shaft-gear is mounted between the inlet cam drive gear and the exhaust cam drive gear. The view at B, which shows the assembly in the cam case, makes clear the type of valve-operating bell crank and unconventional cams employed. These are internal instead of external forms, and they are formed integral with the half time or speed reduction gears. The valve-lifting plungers are provided with adjustments so the distance between the top of the plunger and the valve stem will be very closely regulated.

The valve-operating mechanism at Fig. 98 is employed in another form of Precision engine in which the valves are placed side by side in an extension from the cylinders, both being of the same type and interchangeable. The view at A shows the appearance of the assembly when viewed from the front, and the method of housing the cam-gear case attached to the engine base. The gear used to drive the cam is twice the size of that on the engine shaft, and therefore drives the cam-shaft at one-half engine speed, as is customary. The valves are raised by plungers which rest on the ends of levers that carry the cam-riding rolls. The arrangement of these members, and form of cams used, are depicted at Fig. 98, B. Each of these levers is fulcrumed at its extreme end and carries a cam roller which follows the cam contour with minimum friction.

One objection that has been advanced against valve-in-the-head motors, is that the overhead valve-operating mechanism was subject to rapid depreciation on account of the presence of grit and dirt at the somewhat limited bearing point on the rocker arms. In order to prevent the accumulation of foreign matter, some makers of motorcycle engines are enclosing the inlet valve-gear so it is not only protected from deposits of dirt but makes the engine appear considerably

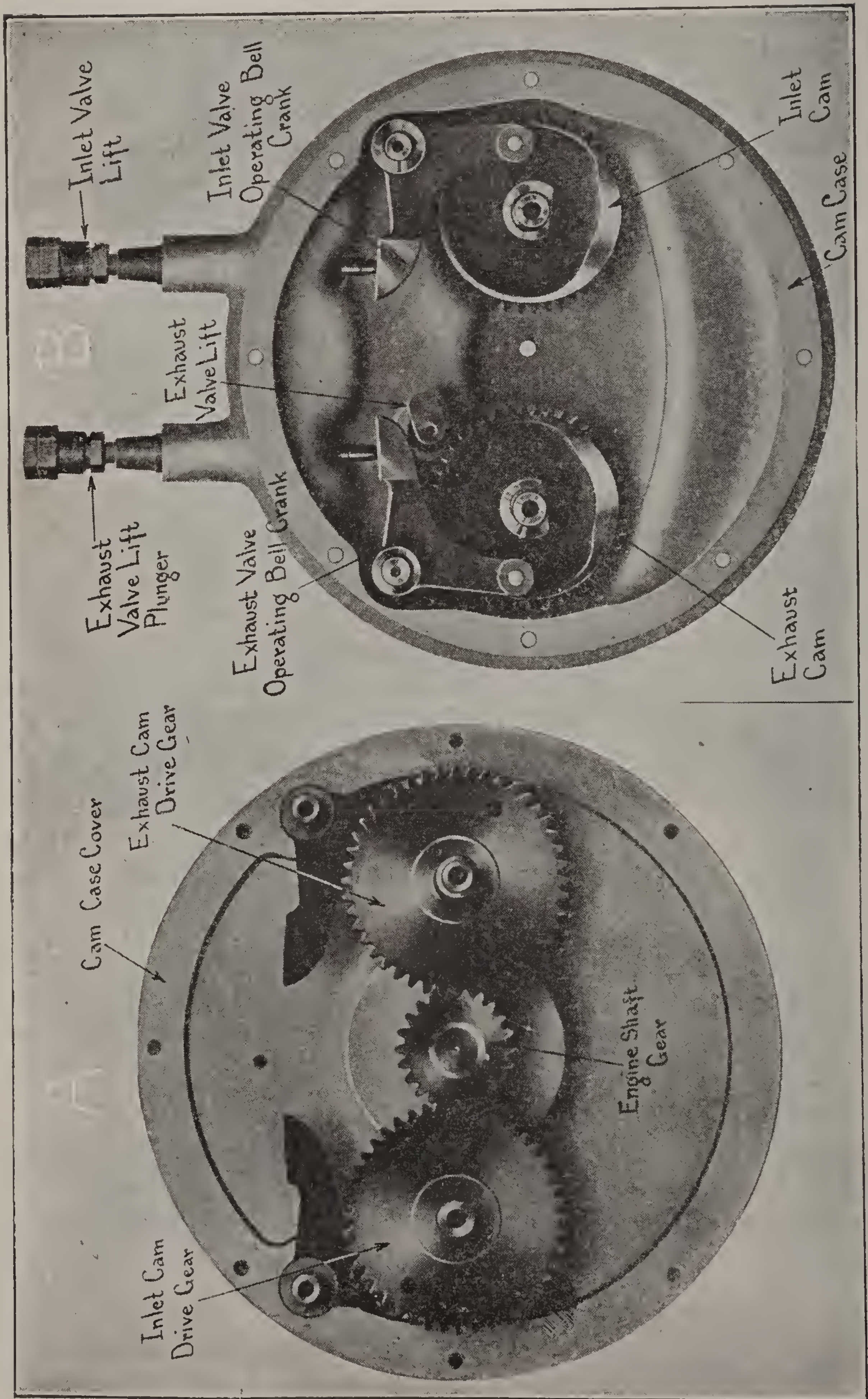


Fig. 97.—Valve Operating Mechanism of Precision Overhead Valve Motors. A—Showing Cam Drive Gear Arrangement. B—Form of Valve Operating Bell Crank and Internal Cams Used.

simpler and actually decreases the noise. The external view of the twin-cylinder power plant at Fig. 99 shows the smooth appearance of the inlet valve-cage, while the method of closing in the rocker arm with a pressed steel cap held in place by two screws can be understood by reference to Figs. 93 and 94.

Valve Timing.—Another important consideration that has material bearing on the power, speed and flexibility of the motorcycle power plant is the valve timing. It is imperative that the valves not only open to their full extent but also that they open in correct relation to the movement of the piston, in order to insure a full charge of fresh gas or thorough expulsion of the exhaust. In the first gas engines which were built to operate at low speed, the usual practice was to open the inlet valve just as soon as the piston started to go down on its suction stroke, and to open the exhaust valve when the piston had reached the end of its power stroke. The inlet valves were closed promptly at the end of the first down stroke of the piston, while the exhaust valve was seated just before the inlet valve opened or at the end of the exhaust stroke. It will be evident that the valves were each opened a period corresponding to one-half revolution of the flywheel, or 180 degrees crankshaft travel.

In endeavoring to secure greater speed and flexibility from the internal combustion motor, which was imperative before it could be applied with any degree of success to vehicle propulsion, the designers, reasoning from well-established steam practice, began to consider giving the exhaust valves a "lead," or to open them before the pistons had reached the end of the explosion stroke. As the exhaust gases had considerable pressure, a large portion of this residue would escape through the open exhaust valves before the piston had reached the end of its power stroke, and during the next up stroke the cylinder would be thoroughly cleared out by the displacement of gas, due to the upward movement of the piston. The control of the valve timing is by altering the relation the timing gears and adjustment of the valve-lifting push rods or tappets bear to the piston travel.

In the engine shown at Fig. 100, the cover has been removed from the cam gear case so the various gears employed in operating the valve-lifting cams and the magneto are shown in proper relation. It will be observed that the timing gear is attached to the crankshaft,

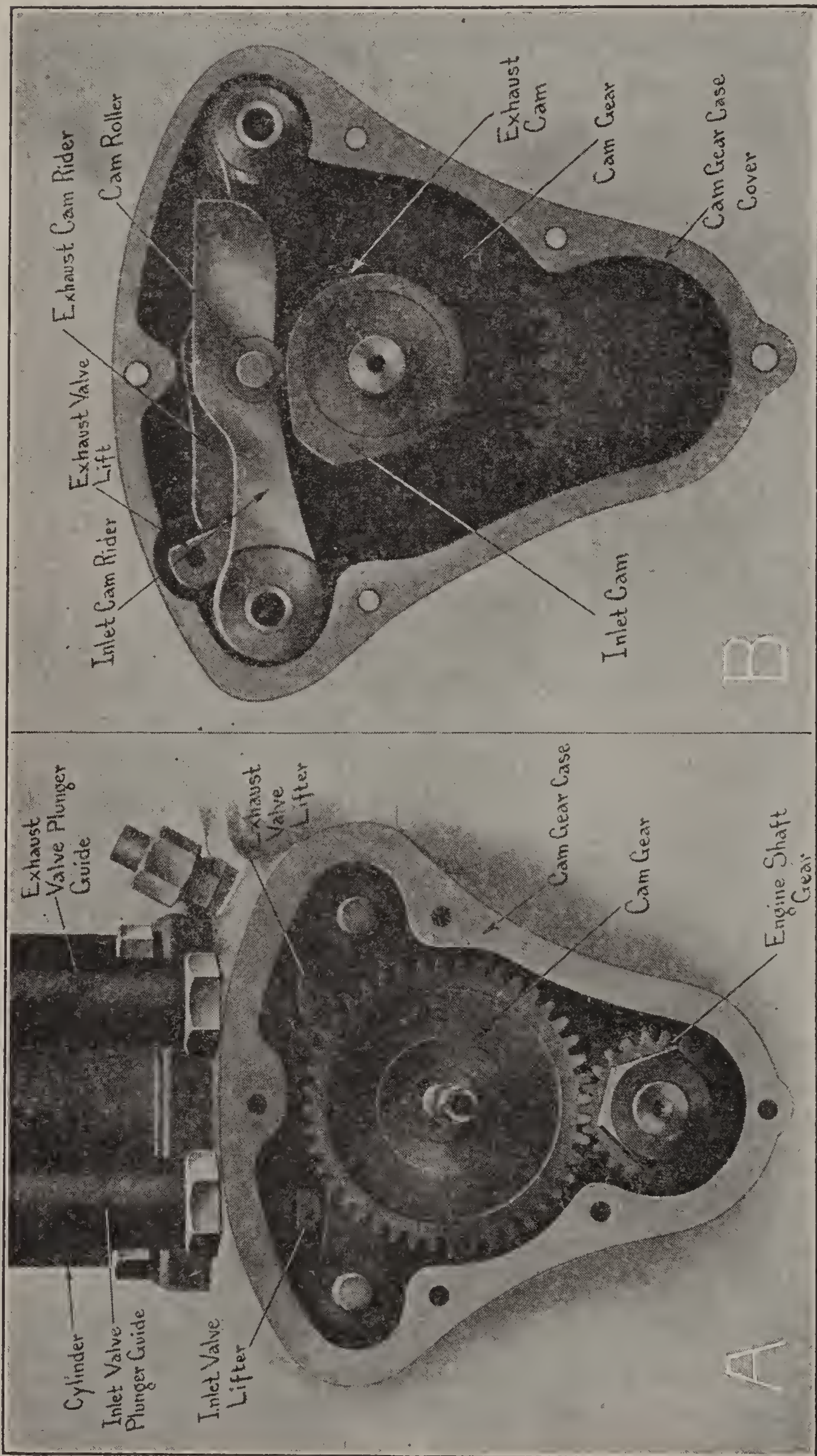


Fig. 98.—Arrangement of Valve Operating Gear of Single Cylinder L Head Precision Motors. A—Timing Gear Case With Cover Removed, Showing Method of Driving Cam Gear From Crank Shaft. B—Outlining Cam Gear With Inlet and Exhaust Cams Integral and Design of Valve Raising Levers.

and that this meshes with cam gears, one of these being employed for each cylinder. In timing the motor after the adjustment of the gears has been disturbed it is necessary to place the distinguishing marks on the various gears as indicated in the illustration. One gear is

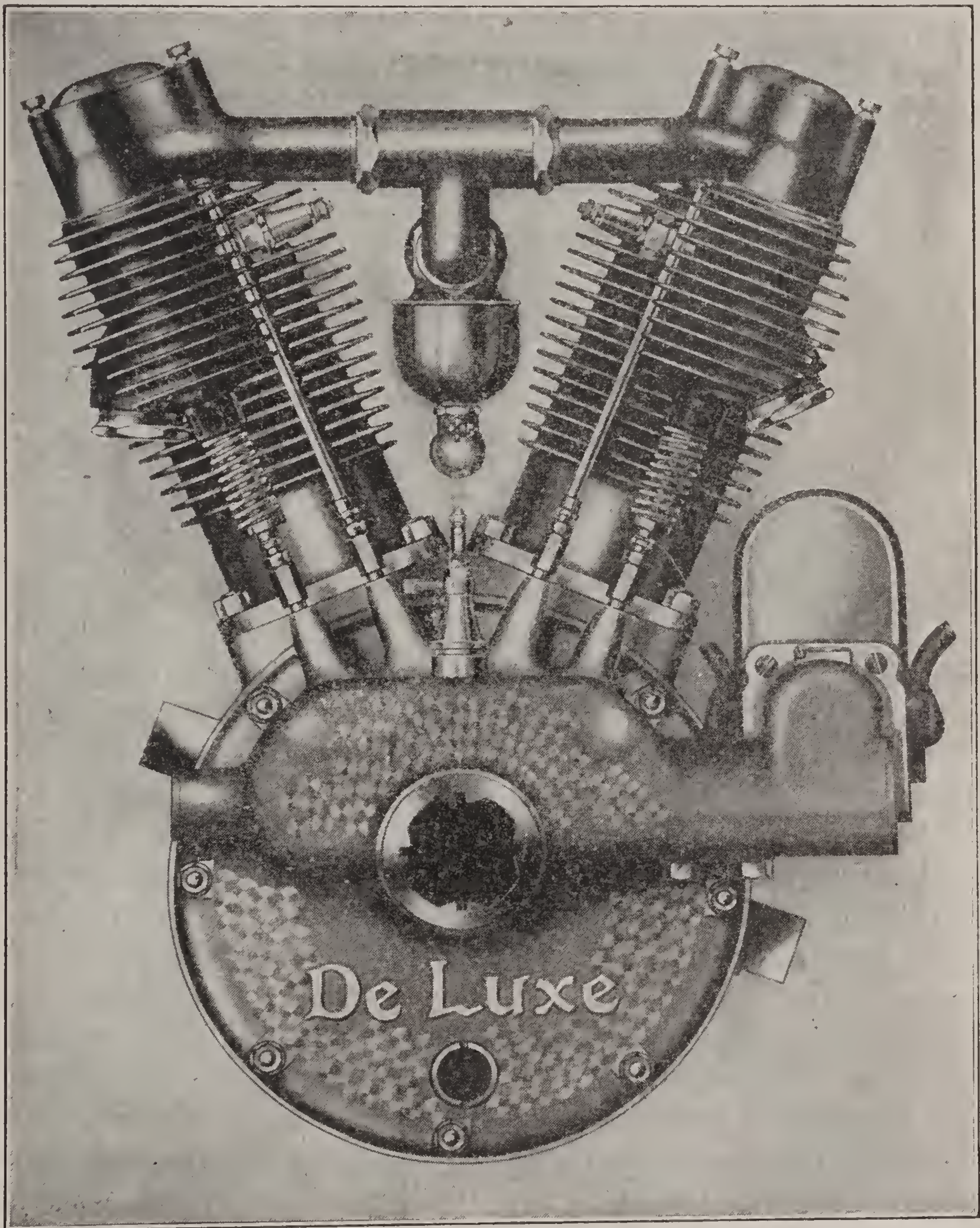


Fig. 99.—The De Luxe Twin Cylinder Motorcycle Power Plant With Enclosed Inlet Valve Operating Gear.

marked F and has an arrow pointing to one of the teeth immediately under the letter. The other cam gear is marked R, and has a similar arrow extended to the gear teeth. The cam and gear assembly marked F is employed for the front cylinder, that marked R is utilized for the rear cylinder. Two arrows are placed on the crankshaft gear, and to secure proper valve timing it is required that the cam gears be replaced so the arrows on the side will register with those on the crankshaft gear. An arrow is also marked on the magneto-drive gear, and when the arrows on the timing gears are in proper register, that on the magneto gear should coincide with a corresponding mark on the timing gear case. The idler or intermediate gears may be replaced without any regard to the way they are meshed, as these will not affect the timing provided that the remainder of the gears are in proper relation to the marks provided as an index for proper resetting.

The view at Fig. 101, which represents a single-cylinder engine with one-half of the cylinder and crank-case removed, shows the position of the piston when the exhaust valve is about to open, and the sectional view through the valve chamber shows the exhaust valve still seated, but its operating mechanism which is indicated in the timing gear case is just about to ride on the point of the cam and open the valve. The exhaust valve in this specific instance opens when the piston is about 7/16 of an inch away from the bottom of the cylinder, measuring from that point to the bottom of the piston. In this case, the exhaust valve starts to open when the crankshaft has traveled 135 degrees from the position at the time the gas was ignited, and the crank-pin must cover an arc of 45 degrees before the fly-wheel will have completed the half revolution corresponding to the downward travel of the piston during the expansion stroke. The exhaust valve should close when the crank-pin has traveled a distance of 193 degrees on the exhaust stroke, which means that the crank will have reached its top center and the piston has started to go down again a distance corresponding to 13 degrees movement of the crank-pin. This represents a downward movement of the piston of but 1/16 of an inch. Just as soon as the exhaust valve closes, the inlet valve opens as shown at Fig. 102. The inlet valve remains open a period corresponding to 10 to 20 degrees movement of the crank-pin after the piston has reached the bottom of the suction stroke, or has covered

approximately 3/32 of an inch upward movement on the compression stroke.

The actual duration of the exhaust period is therefore the sum of 45 degrees and 193 degrees, or 238 degrees. The inlet valve remains open a period corresponding to 180 to 190 degrees crank-pin travel.

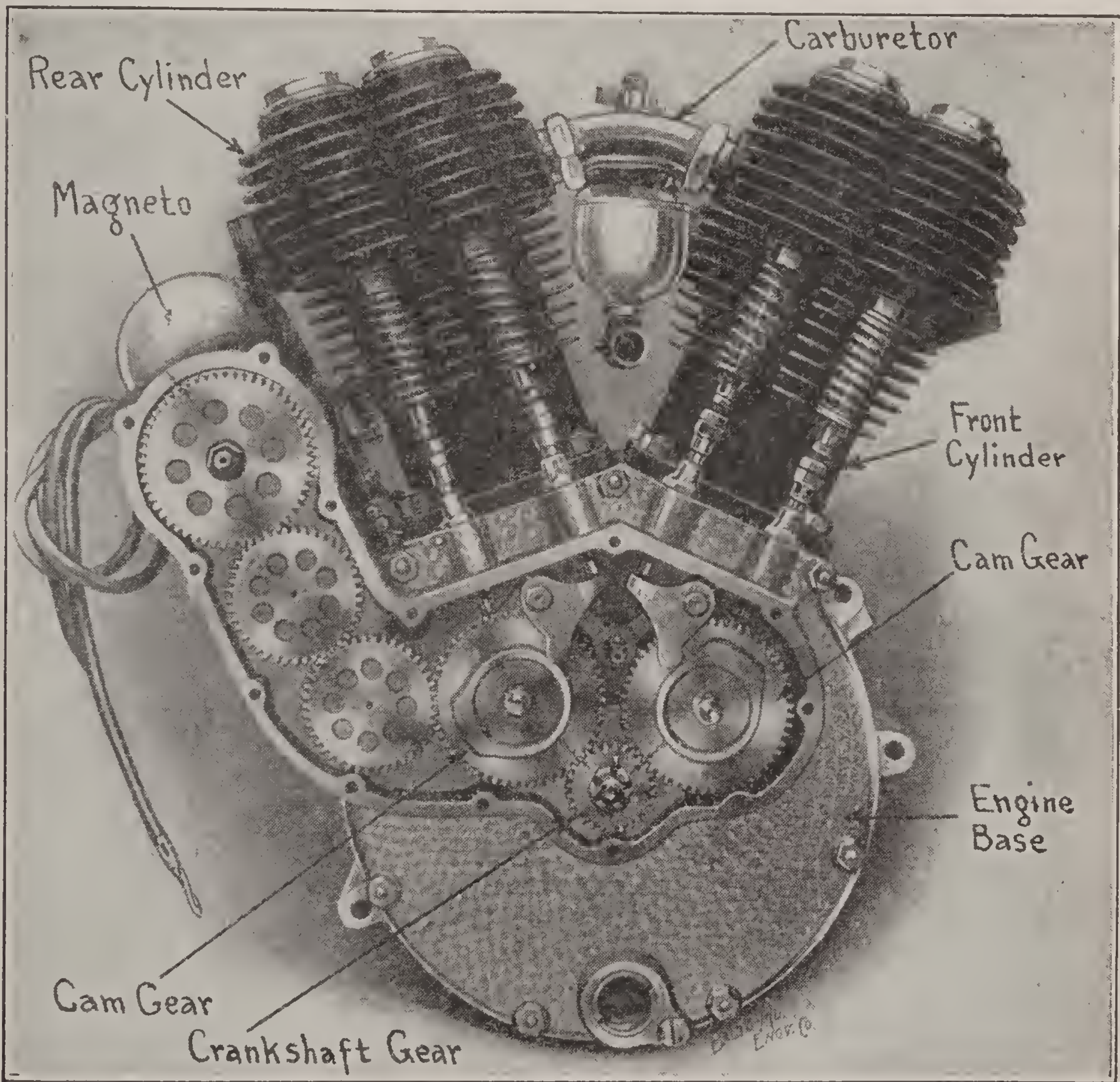


Fig. 100.—Reading-Standard Twin Cylinder Motor With Cover Removed From Timing Gearcase to Show Designs of Cams and Marks on Gears to Indicate Correct Setting as Determined by the Factory.

The reason that the inlet valve is allowed to lag and that the exhaust valve does not close exactly on center is that the gas has acquired a certain degree of momentum during the upward stroke of the piston, and this may be taken advantage of in securing more thorough charg-

ing or scavenging if the valve remains open for a time after the piston reaches the top of its stroke. The exact duration of the inlet and exhaust periods depends upon a number of factors, and will vary in practically all engines by a few degrees crank-pin travel.

It is generally recognized, however, that it is imperative to open the exhaust valve early if high speed and efficiency are to be obtained,

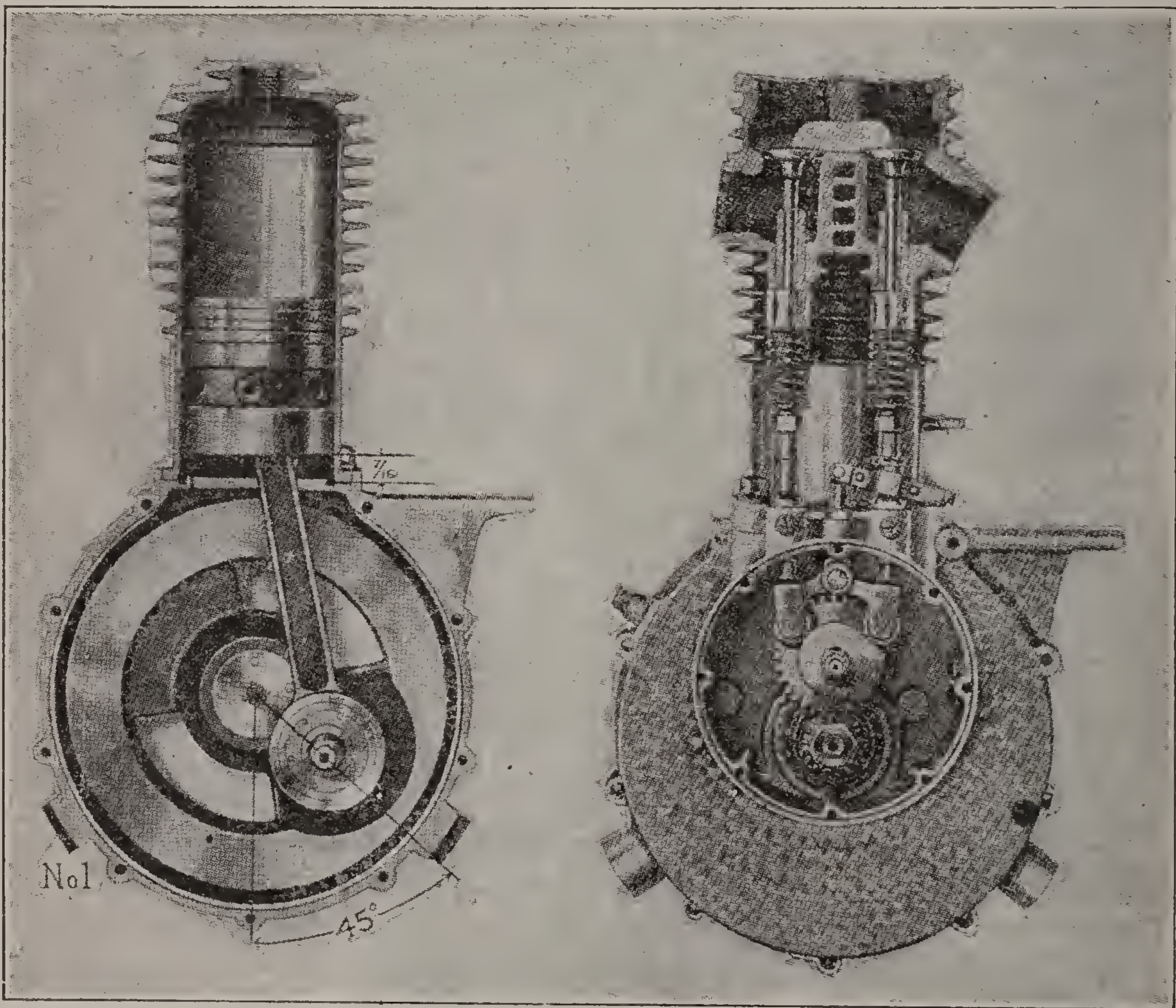


Fig. 101.—Sectional View Showing Point in Crank Pin Travel at Which Exhaust Valve Opens on Thiem Single Cylinder Motor.

and that some benefit is derived by deferring the opening of the inlet valve until a condition of partial vacuum exists in the cylinder. If the inlet valve opens late, the gas will tend to rush into the cylinder faster than would be the case if it opened just after the piston had reached the top of its scavenging stroke. The valve opening may be varied very accurately by suitable adjusting members on the valve-operating plungers, or by a threaded adjustment of the tappet rod, or

the use of a small screw at the end of the rocker arm to contact with the valve stem. The proper position of a rocker arm on a valve-in-the-head motor, when the valve is closed, is shown at Fig. 103, A. There should be 0.010 inch clearance between the valve stem and the end of the rocker arm when the valve is fully closed, in order to provide for lengthening of the valve stems due to expansion from heat. The position of the rocker arm with the valve half open is shown at B,

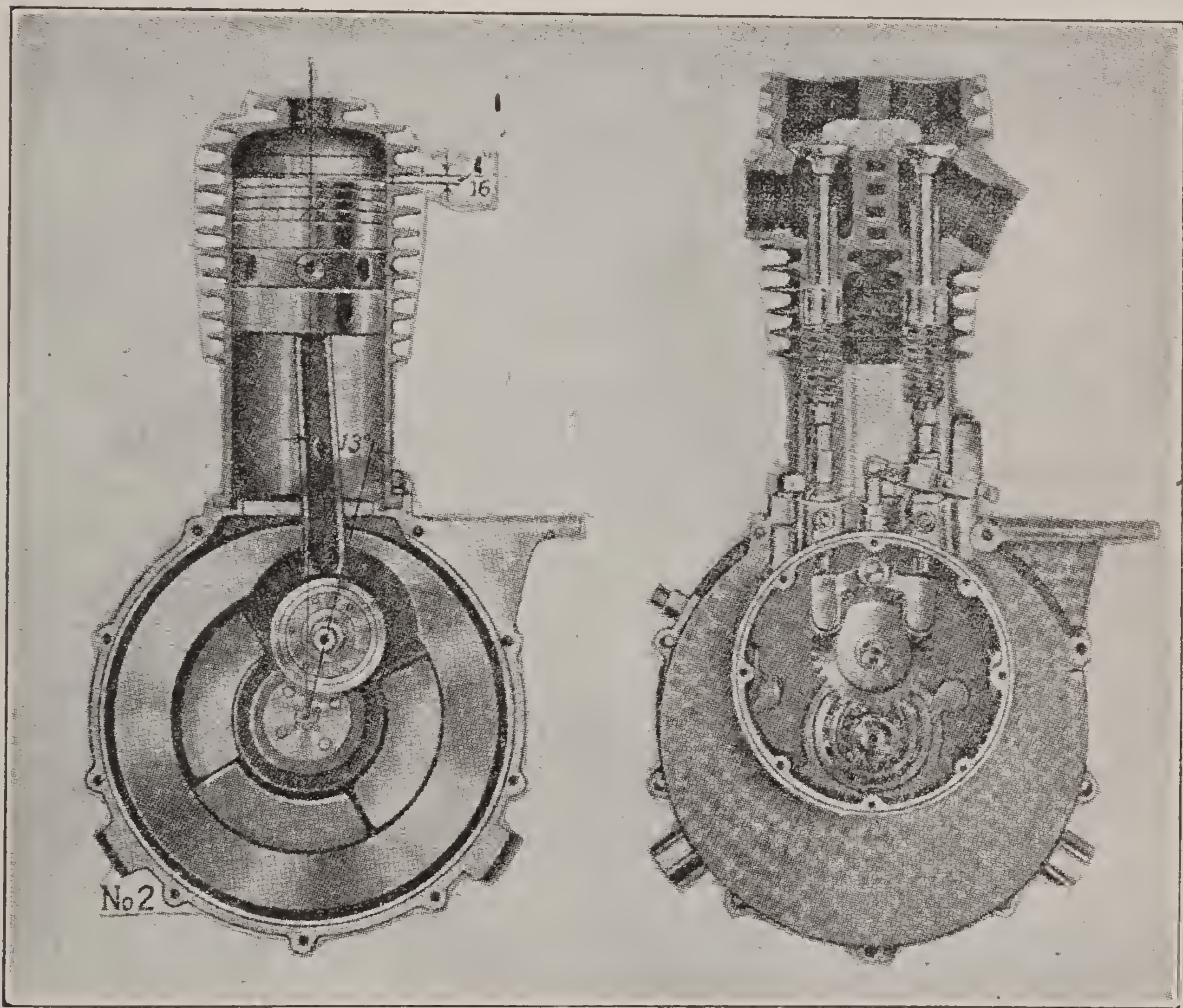


Fig. 102.—Sectional View Showing Point in Crank Pin Travel at Which Exhaust Valve is Fully Closed and When Inlet Valve Begins to Open.

and the angle assumed by the valve lever when the valve is fully opened is shown at C. If the fulcrum is exactly at the center of the rocker arm, the opening or lift of the valve may be readily ascertained by measuring the travel of the tappet rod center line which is indicated in the illustration by the distance between the diverging center lines.

Pistons and Rings.—Pistons are invariably made of cast iron in motorcycle power plants, though steel has been employed to a limited extent in aeroplane and very high-speed automobile and cycle motors. The piston is always less in diameter than the bore of the cylinder, in order to provide space for an oil film between the piston and cylinder walls. In order to prevent leakage of the gas, elastic or spring packing members called piston rings are inserted in grooves in the piston. It is common practice to provide three rings which are usually placed above the wrist-pin. In some constructions, two rings are placed at the top and one at the bottom of the piston, and

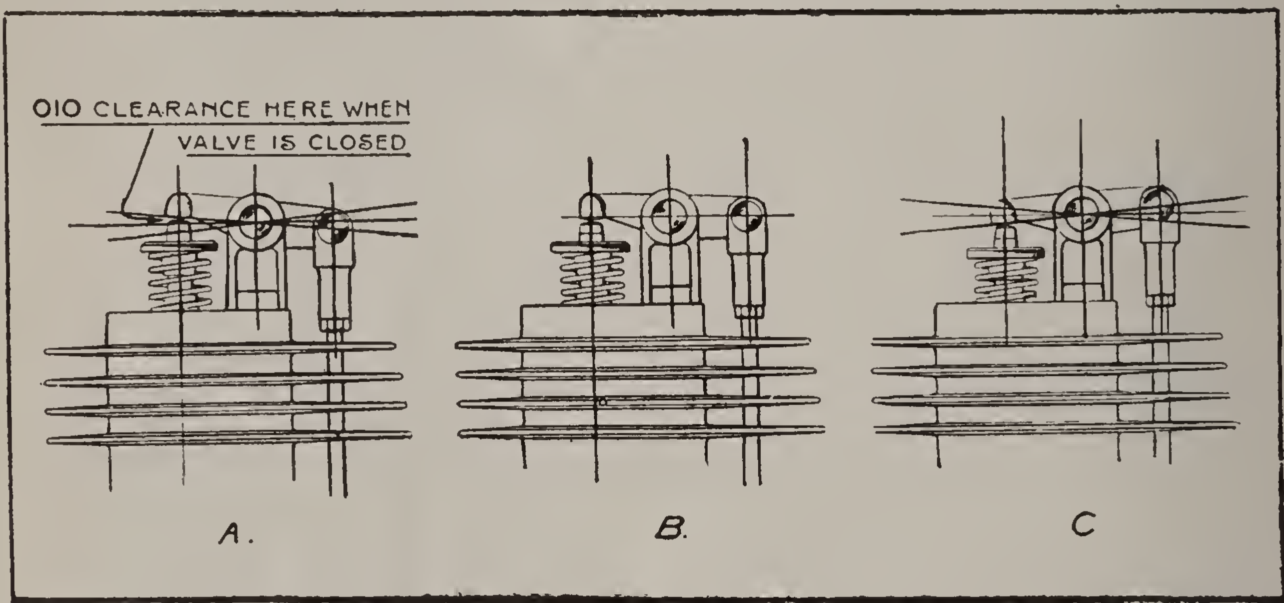


Fig. 103.—Positions of Rocker Lever Used in Depressing Overhead Valves. A—Showing Clearance When Valve is Closed. B—Valve Half Opened. C—Rocker Arm Position With Valve Fully Opened.

it is contended that this makes for steadier support of the piston as well as preventing, as much as possible, the leakage of compression.

The most popular form of piston is the flat-top type depicted in the assembly of engine parts at Fig. 104 and very clearly outlined in the various sectional views of complete power plants previously presented. In some engines, domed-head pistons are employed, while those used in two-cycle motors have a projecting ridge or raised portion to deflect the fresh gas coming in from the transfer passage to the top of the cylinder. The piston rings are of two general forms, one termed "eccentric" because the ring is thicker at one portion, and the "concentric" in which the ring is of uniform thickness and the

circles representing the inner and outer peripheries of the ring are concentric to each other. In order to permit of installation of the piston rings on the piston, they are split at one point, and have sufficient elasticity so that they may be snapped in place in the grooves made to receive them on the piston wall. Two forms of joints are used in piston rings; one is the diagonal cut, the other is termed the "stepped" joint. Some makers provide a small pin in the ring groove

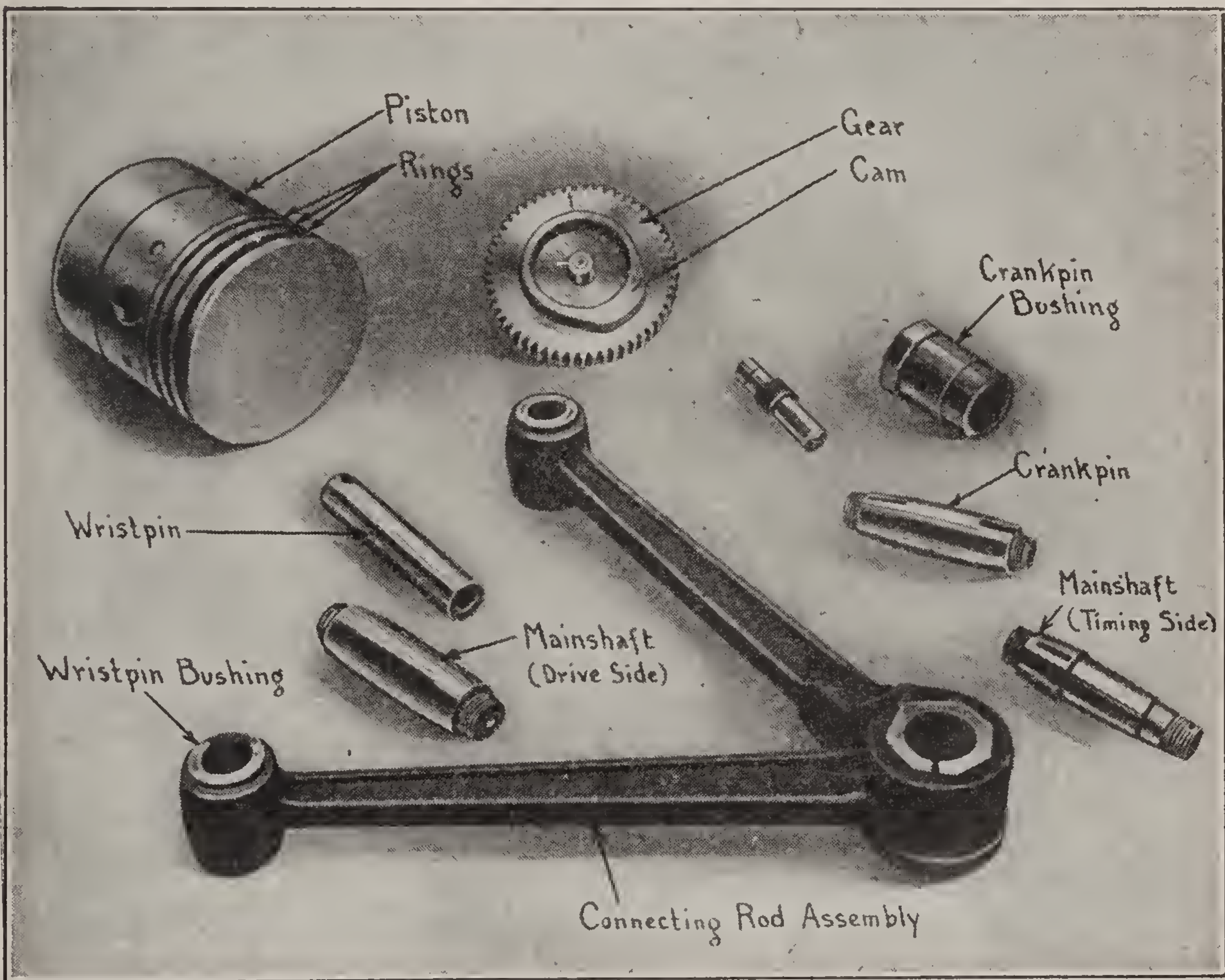


Fig. 104.—Group Showing Some of the Internal Parts of the Reading-Standard Twin Cylinder Motor. Note Arrangement of Connecting Rod Assembly.

to keep them from working around, because if the slot in the three rings should happen to get in line, there is apt to be a loss of compression with the diagonally split rings. With the stepped joint, it is not so important to use the stop pins as the character of the joint is such that leakage is reduced appreciably, and it is considered good practice to have the rings free to move, because it makes for more

even wear on the cylinder wall. The piston rings fit their grooves snugly but yet are free to move circumferentially though not up and down in the groove.

The argument advanced in favor of the dome piston top is that the arched construction is stronger, and that the liability of accumulations of oil being deposited on the arched head is less than with a flat head which in some cases may actually have a slight depression at its center. The flat top form is easier to machine.

Wrist Pin and Connecting Rod Arrangements.—The upper

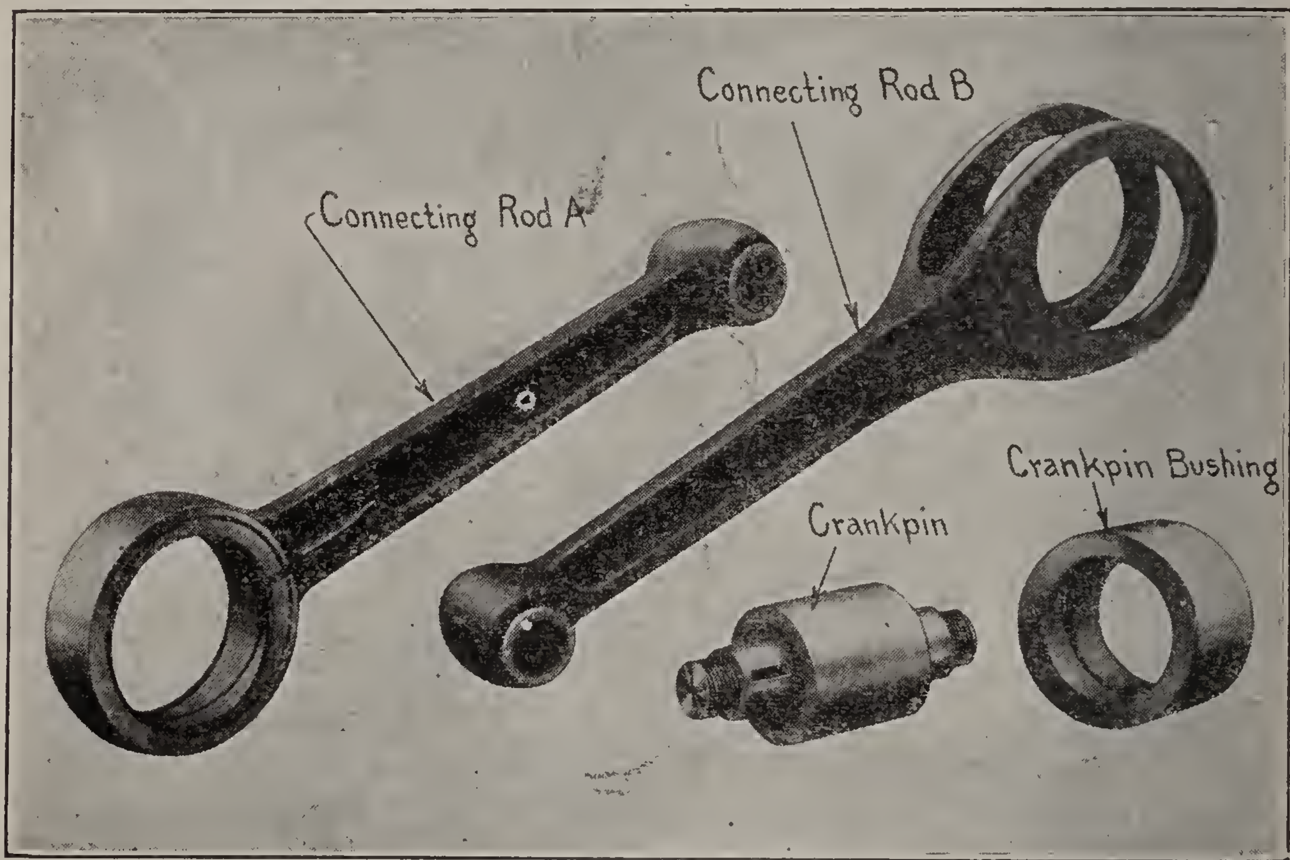


Fig. 105.—Components of Twin Cylinder Connecting Rod Assembly Taken Down to Show Design of Connecting Rod Big End.

end of the connecting rod oscillates on a short steel shaft that passes through suitable bosses in the piston. Wrist pins are usually of hardened steel and may be of solid cylindrical or tubular section. The tubular section is preferred because oil may accumulate in the interior of the hollow wrist pin which acts as a reservoir for its retention, and from which it may be directed to the wrist-pin bushing, usually of phosphor bronze. The retention of the wrist pin is by positive means, because if this member is permitted to move sideways in the piston it is apt to wear a wide groove in the cylinder wall, as the hard and

sharp edges of the wrist pin act the same as a planer tool when the piston reciprocates in the cylinder. These grooves generally ruin the cylinder, because they are so deep that there would not be enough metal left for strength if the cylinders were rebored. The commonest method of wrist pin retention is to use a set screw which passes through the boss of the piston and into the wrist pin. If that member is hollow, a small split pin may be passed through the end of the set screw projecting into the wrist pin interior to prevent it from backing out. In some cases, the set screw is kept from backing out by a lock nut.

The wrist pin does not always have a bearing in the upper end of the connecting rod, as sometimes the connecting rod is clamped to the wrist pin member so this member must oscillate in suitable bushings pressed into the piston bosses. This method of construction has an important advantage, inasmuch as considerably more bearing surface is obtained than when a bushing is forced into the upper end of the connecting rod, which must be comparatively narrow in order to fit between the bosses on the piston. Another advantage is that the wrist pin is positively clamped and is thus prevented from end movement. The various common methods of wrist pin retention may be clearly understood by referring to the many sectional views of typical motorcycle power plants presented in this and the preceding chapter.

Connecting rods are invariably steel drop forgings and are made in two main types. The simplest of these is the one-piece rod which is used on engines having built-up crankshafts, while the other is necessary on multiple-cylinder engines using one-piece crankshafts, and is a two-piece form because the lower end is divided so a portion forms a cap for the bearing. Half of the main bearing is attached to the connecting rod, while the other half of the bushing is firmly secured to the connecting rod cap. The cap and connecting rod are joined together by substantial bolts.

The connecting rod of a single-cylinder engine is very simple, and is of the general form indicated at Fig. 105, A. In the majority of twin-cylinder engines, one of the connecting rods is forked at the lower end, as shown at B, Fig. 105, and the rod that works in connection with it has a single end which fits between the fork members of the other. Both rods work on a common crank pin. Connecting rod A,

at Fig. 105, is provided with a bushing having a sufficiently large bore so that it will work freely on the outside of a large bushing that is forced tightly in place in the fork sides of connecting rod B. The bushing that fits the forked rod is adapted to bear directly on the crank pin. It will be apparent that the bushing in connecting rod A is employed on an oscillating bearing, whereas that in connecting rod B revolves with the crank pin, and is therefore subject to wear on its inside by the friction of the crank pin and on its exterior by the bushing of connecting rod A.

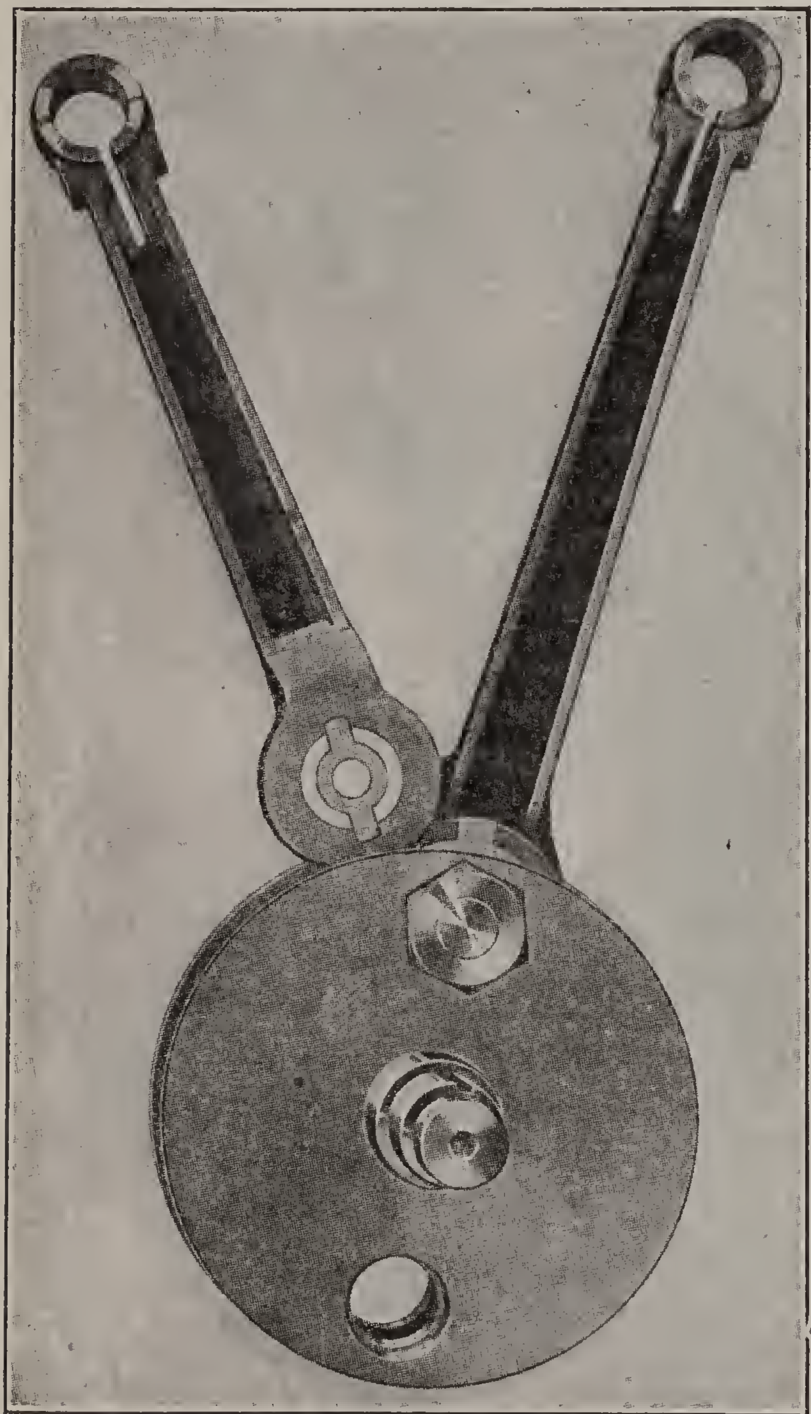


Fig. 106.—Connecting Rod and Crankshaft Assembly of the De Luxe Twin Cylinder Motor.

Another method of double connecting rod arrangement is shown at Fig. 106. In this, the main connecting rod encircles the crank pin and carries a lug above the crank pin to which a shorter rod is attached. The long member is usually called the "master" connecting rod.

The connecting rod arrangement of the Premier (English) engine differs considerably from conventional practice because the arrangement of the rods is such that both pistons move together in their respective cylinders, and reach the ends of the up and down stroke simultaneously. With

the connecting rod arrangement commonly employed on twin-cylinder V-motors, one of the pistons reaches the end of its stroke in advance of the other, and it is impossible to obtain an even sequence of explosions, i. e., to have them separated by equal intervals. With reference to the Premier connecting rods assembly, which is depicted at Fig. 107 in connection with the fly-wheel assembly and at Fig. 108 in the engine interior, rod A conforms to conventional practice and its lower end encircles the usual form of crank pin joining the fly-wheels to form a crankshaft assembly. Rod B, however, is a forked member that fits bosses cast on the fly-wheel. The arrangement of these bosses is such that as the fly-wheel assembly revolves the pistons will move exactly the same distance, and it is, therefore, possible to have the explosions just as evenly spaced as when a double cylinder opposed engine is used or a twin-cylinder tandem arrangement with both connecting rods attached to a common crank pin.

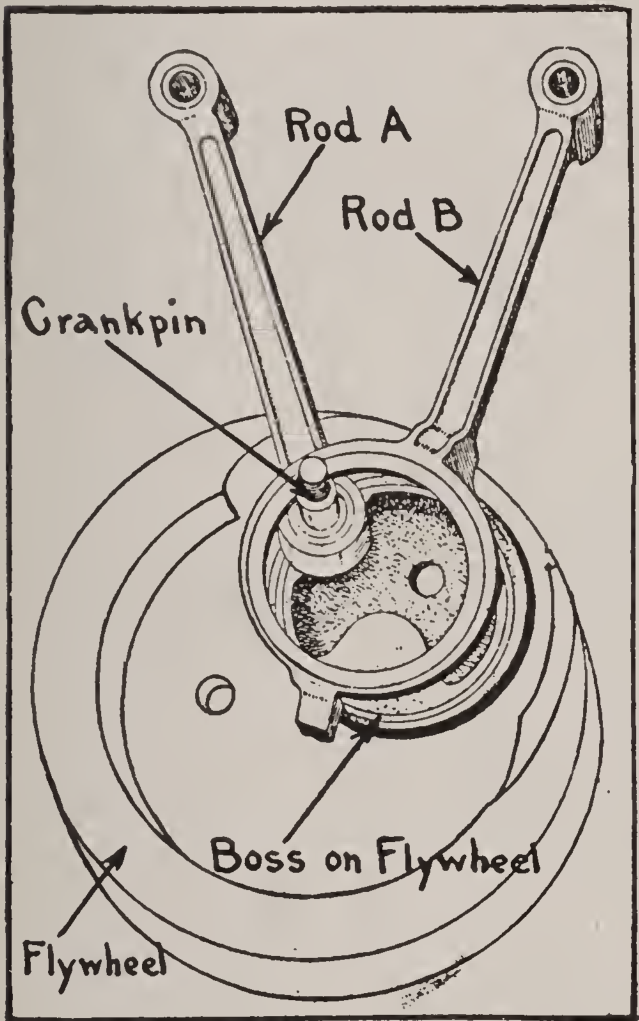


Fig. 107.—Unconventional Connecting Rod Arrangement Utilized in Premier Two Cylinder Motor.

Crankshaft Forms and Fly-wheels.—The common construction of the crankshafts of one and two cylinder motorcycle power plants is a built-up type in which the fly-wheels form an important part of the assembly. In the four-cylinder forms, the crankshaft is a four-throw, one-piece pattern just as in automobile practice. A typical built-up crankshaft and fly-wheel assembly is outlined at Fig. 109. In this, the crank-pins are pressed into suitable bosses at the center of the fly-wheel webs. The crank-pin is a tight fit, and is forced in place with an arbor press. To prevent loosening, a key is added as a

further precaution, and the end of the pin is riveted over. The crank pin is provided with a threaded portion at each end, and clamping nuts are used to draw the two fly-wheels tightly in place against a shoulder on the crank pin. The assembly is therefore composed of two fly-wheel castings, which in this case are duplicate members,

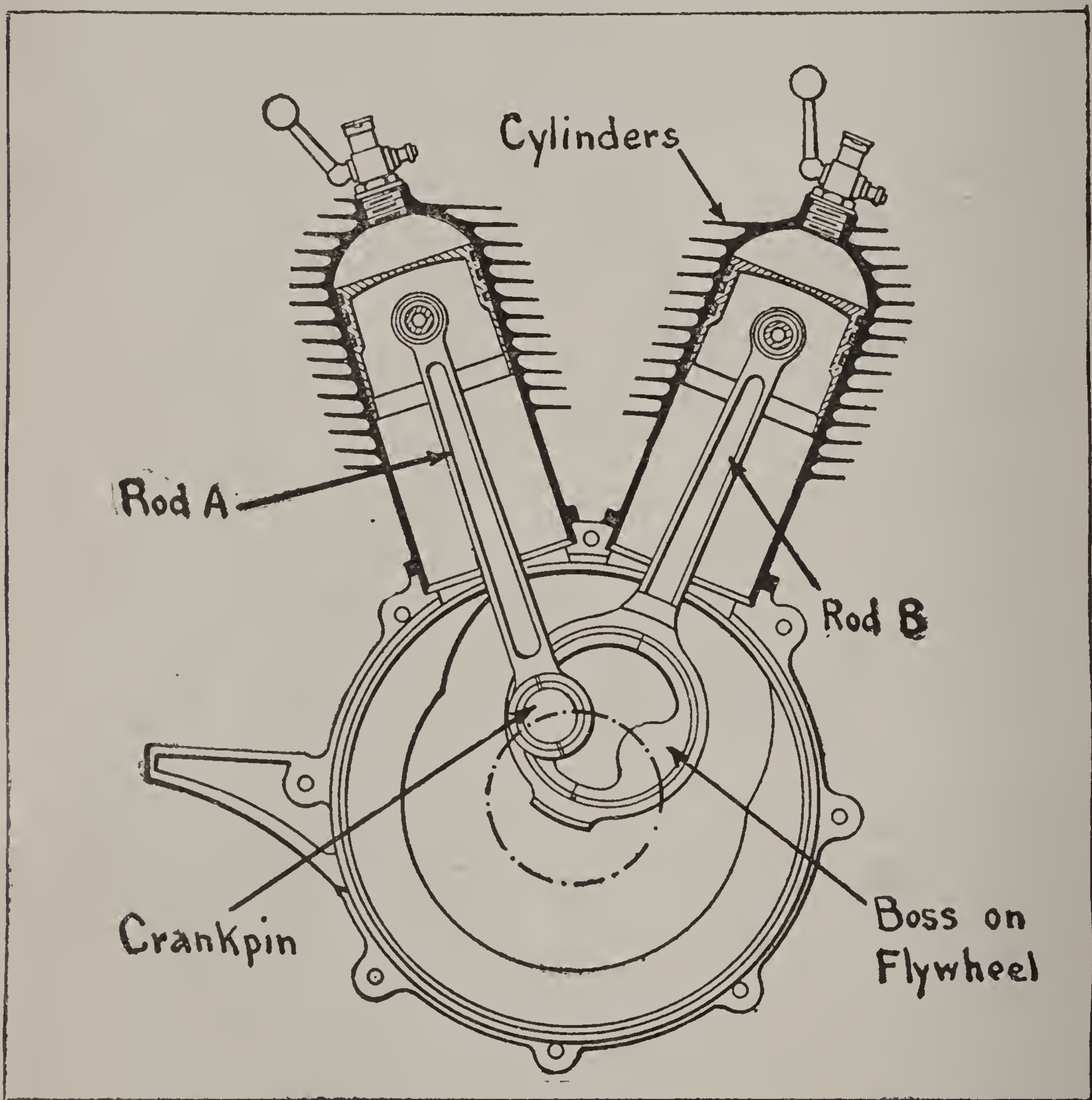


Fig. 108.—Diagram Showing How Premier Connecting Rod Arrangement Permits Both Pistons to Reach the Top or Bottom of the Stroke Simultaneously.

except that one is a right and the other is a left; the crank-pin and the two portions of the main shaft that are riveted in the fly-wheel hubs. In taking this assembly apart, the fly-wheel and main shaft relation is not disturbed because the two fly-wheels may be easily separated

to release the crank-pin and connecting rod by loosening and removing the clamping nuts on the crank pin. Other forms of built-up crankshafts similar in general design to this one are shown in sectional views of power plants in various portions of this treatise.

The crankshaft outlined at Fig. 110 is the one used on the new Triumph (English) two-cylinder vertical tandem motor. The crankshaft is a one-piece pattern similar to that employed in automobile practice, and the connecting rods are of the two-piece form with a removable lower cap portion to permit their assembly on the one-piece shaft. The crankshaft shown at Fig. 111 is that used on the Iver-Johnson twin motor, and employs a double crank-pin which is arranged so the cylinders fire at equal intervals the same as in the double cylinder opposed type. The construction is such that the fly-wheel castings are securely attached to the drop-forged crank which has the crank pins in staggered relation. With this arrangement, the cylinders are not exactly in the same plane, i. e., their center lines do not coincide with the center line of the crank-case as is common practice. One cylinder is set to the right and the other to the left of the engine center, in order to allow for the double crank-pin arrangement.

The crankshaft arrangement of a typical four-cylinder engine with one of the connecting rods and its piston in place is shown at Fig. 112. This crankshaft has four crank-pins joined together by a series of web members and three main journals. The entire assembly is forged in one piece, and follows automobile practice in all respects except that of size. Two of the crank-pins are on the same plane so that two of the pistons travel up and down together. The usual arrangement is to have the two center pistons move in conjunction and the two end ones to go up while the center ones are going down and *vice versa.*

The method of fly-wheel attachment on the four-cylinder crankshaft depicted is clearly outlined at Fig. 92. The fly-wheel hub is tapered to fit the taper on the crankshaft, and is also keyed in place to prevent the fly-wheel from turning. A substantial clamp nut on the threaded end of the crankshaft serves to keep the fly-wheel pressed firmly on the taper. The endeavor of the designers is to make the fly-wheels as large as the design of the engine permits and to have the rims reasonably heavy because the farther away the weight is

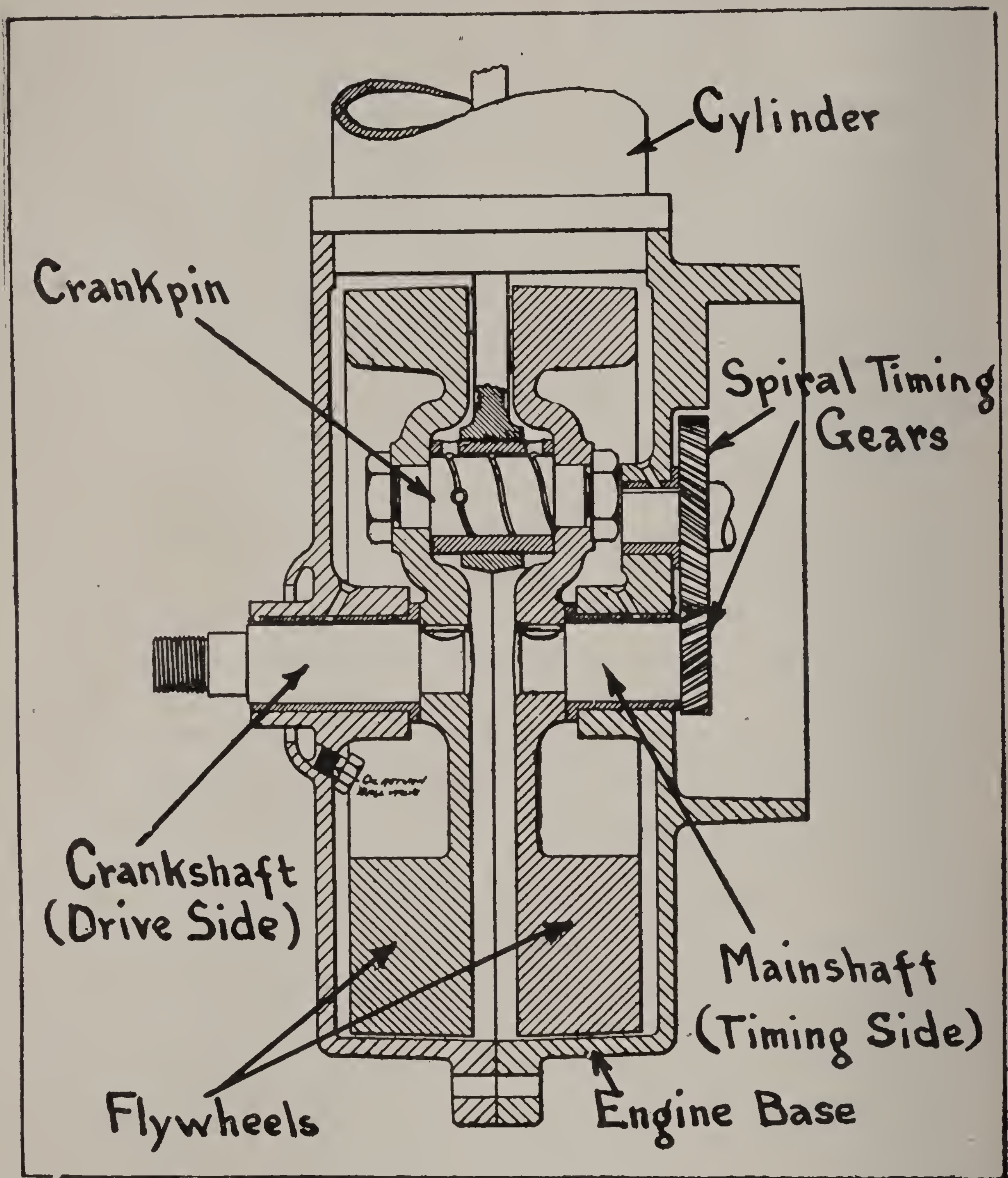


Fig. 109.—Sectional View of Crank Case of AMC Motor, Showing One Method of Assembling Built Up Crank Shaft in Which the Flywheel Webs are Utilized for Supporting the Crankpin.

carried from the crankshaft center the more effective does the fly-wheel become as an evener of engine movement. As has been previously explained, the momentum acquired by the fly-wheel during the expansion or power stroke of the engine is depended on to keep the pistons, valves, etc., in operation during the strokes in which no

power effort is being applied to the crankshaft, and under conditions where a decided resistance may be offered to piston movement, as during the compression stroke. Heavy fly-wheels permit an engine to run steadily at low speed and also reduce vibration. The size and weight of the fly-wheel rim depends upon the size of the cylinder and the amount of compression. While most fly-wheels used in motorcycle engines are of cast iron, some makers employ steel forgings even in the built-up form of crankshaft. The fly-wheel of a single-cylinder or a two-cylinder V-engine usually has incorporated with it the counterweights provided to balance that of the reciprocating parts and to promote smooth running.

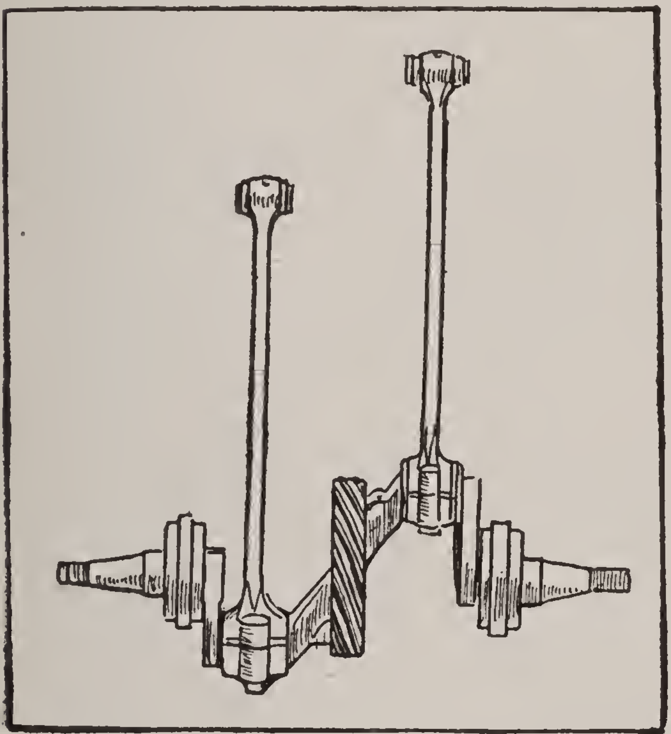


Fig. 110.—Crankshaft Arrangement of Triumph Two Cylinder Vertical Engine.

Engine Base Design and Construction. — The conventional method of constructing the crank-case of a one or a two cylinder motorcycle power plant is to form that member in two pieces, which join together on the engine center lines. The two halves are made of aluminum alloy, and the joints are of the matched form, in order to make the crank-case oil-tight. The timing gear chamber is usually cast integral with one of the halves of the crank-case. The two portions are clamped tightly together by through bolts, extending from one side to the other. The timing gear case is sometimes known as the distribution chamber, and is either provided with a cover or is in itself removable, in order to gain access to the timing gears and valve-operating mechanism. The aluminum crank-case is preferred, though on some cheap engines cast iron has been employed. The only objection against the cast iron is that it weighs nearly three times as much as the lighter alloy commonly used. The cast iron is equally strong and will hold threads better than the softer metal. This method of crank-case construction is shown at Fig. 74.

Another form in which the crank-case member itself is the full width of the engine and not divided vertically in the center is shown at Fig. 77. In this, a removable side plate enables one to gain access to the engine interior and is securely held in place against the crank-case proper by a series of studs.

When multiple-cylinder engines are used, as at Fig. 92, automobile practice is followed in that the crank-case is made in two portions and is split horizontally. The upper portion serves as a base for attaching the cylinders and also carries the main bearings, and the lower portion is utilized as an oil pan and is not subjected to any strain. The engine is supported in the frame by lugs cast with the upper half of the crank-case.

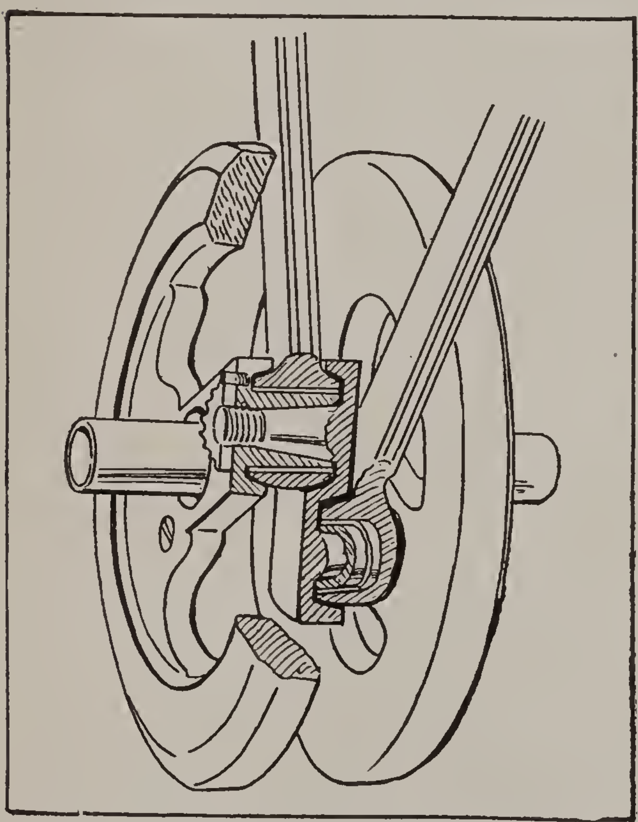


Fig. 111.—Crankshaft Arrangement of Iver-Johnson Twin Motor.

The crank-cases of most engines are provided with some form of gauge glass, in order that the rider may be able to ascertain the amount of oil present in that member. In single and double cylinder engines, a non-return ball check valve is often screwed into the crank-case to permit the air compressed therein, each time the piston moves down, to escape, and usually a small piece of copper tube directs the escaping air to a point underneath the crank-case to insure that the oil with which the air is saturated will not soil the machine. The bearings used in the crank-case may be of two forms, the plain bushing, made of phosphor bronze or other suitable bearing metal, or anti-friction bearings of the ball or roller type. The four-cylinder power plant depicted at Fig. 92 uses plain bushed bearings while that at Fig. 74 has anti-friction bearings of the ball type to support the crankshaft assembly. The engine at Fig. 79 is a plain bearing form throughout as the main bearings, as well as those at the upper and

lower end of the connecting rod, are in the form of bronze bushings forced in place in the crank-case bosses.

Plain and Anti-Frictional Engine Bearings.—Decided advantages are obtained when ball or roller bearings are used to support the crankshaft, because these not only simplify the lubrication problem but they also reduce friction to a minimum, which makes the engine freer running. It is claimed that engines fitted with anti-friction bearings are more "lively," and are faster than the plain bearings forms. Anti-friction bearings are well adapted to this work, and the successful application of ball and roller bearings in racing

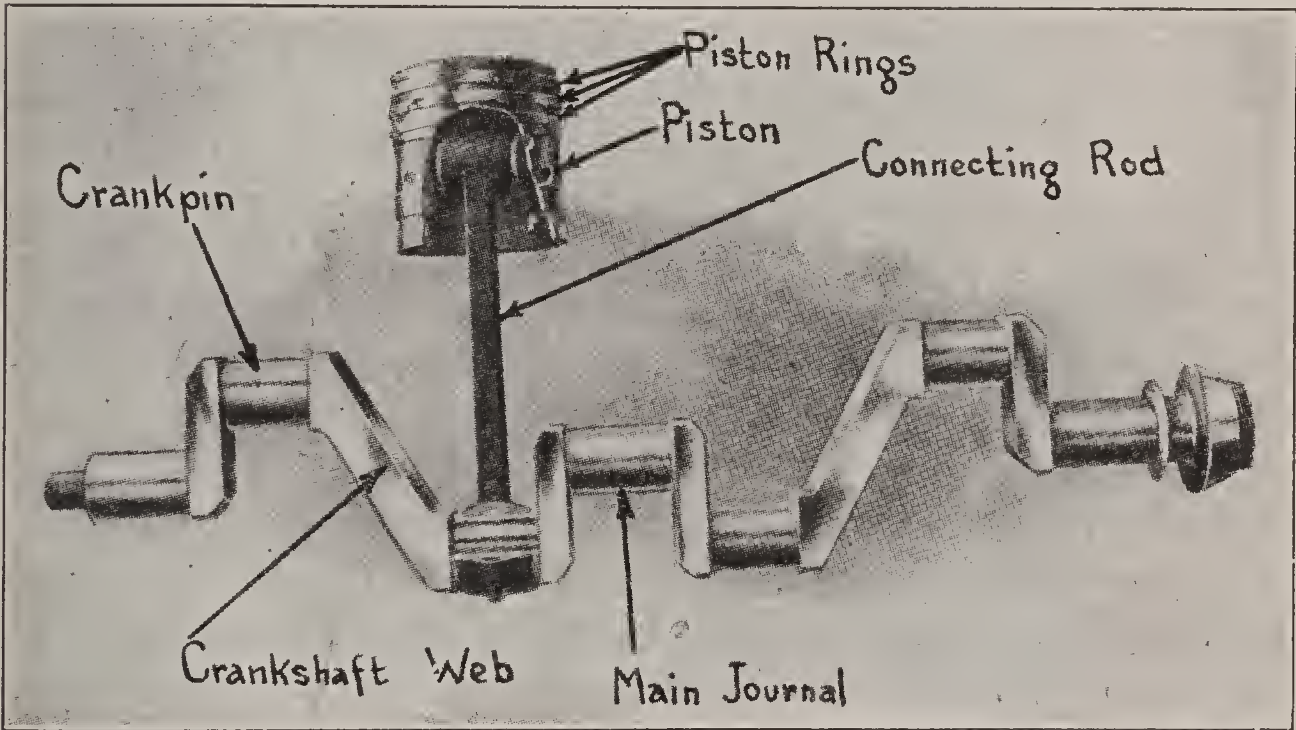


Fig. 112.—Four Cylinder Crankshaft of the Three Main Bearing Type.

motors has demonstrated forcibly the advantages of substituting rolling for sliding friction at all points where copious lubrication is questionable. To use bearings with rolling members successfully, it is necessary to not only make proper size selections but to install them correctly as well as make provision for adequate lubrication, though bearings of this form will run with considerably less oil than plain bushings. As much less heat is evolved through the reduction of internal work due to friction, anti-friction members will prove more enduring and be capable of more extended periods of operation with materially less lubricant, which is depended on in a plain bearing for

separating the metal surfaces and at the same time to conduct away the heat evolved at high speeds due to rubbing of surfaces over each other.

In order to prove that space limitations, to which motorcycle designers adhere so closely, make it difficult to use properly designed journals of the plain bearing type, the reader is asked to study the following brief analysis of the loads present upon a typical connecting-rod assembly using plain bearings and depicted at Fig. 113, and the bearing area provided to resist them. In this, rod *A* is the member attached to the main bushing encircling the crank-pin, while rod *B* is a forked member with the big ends bearing upon the outer surface of the main bronze bushing. The bore of the main bushing is 1¼ inches, its length is 1½ inches. The outside diameter is 1¾ inches, and the width of the forked connecting rod members is 7/16 inch each side. The projected area of the bushing serving rod *A* can be represented by a rectangle 1¼ inches by 1½ inches, which has an area of 1.875 square inches. The projected area of the bearing surfaces serving rod *B* can be represented by a rectangle ⅞ inch by 1¾ inches and has an area of 1.53 square inches.

Before considering the application of anti-friction bearings, let us first briefly review some of the conditions governing plain bearing construction, and then we can understand how the motorcycle designer is forced to make his bearing design, especially as relates to connecting-rod big ends, a compromise that will endeavor to reconcile widely differing factors. Some of the essentials considered in plain bearing designs, are: Proportions and dimensions of bushing as relates to diameter and length; selection of suitable bearing metal; the amount of clearance to be allowed between shaft and bearing, and provisions for lubricating. Considering first the proportions, these depend upon various conditions, such as: Size of the shaft, which must be strong and stiff and which must be of sufficient diameter to obtain this strength, and enough length so the bearing pressures will not exceed a certain value in order to retain an oil film. Contrasted to these are the opposing conditions that circumferential or rubbing speed must be low to reduce the work of friction (which calls for small diameters) and also that the bushing length be held to a point where there can be no concentration of pressure from deflection (which calls

for short bearings) on any limited area of the bushing surface.

As to proportions, most engineering authorities recommend that engine bearings be at least 1.5 times as long as the diameter of the shaft where space considerations permit. In the main bearing of the connecting-rod assembly described, the ratio is considerably less than this as the length is but 20 per cent. greater than the diameter, and in the bearings of rod *B*, the length is but half the diameter. Here we have the first departure from good engineering practice.

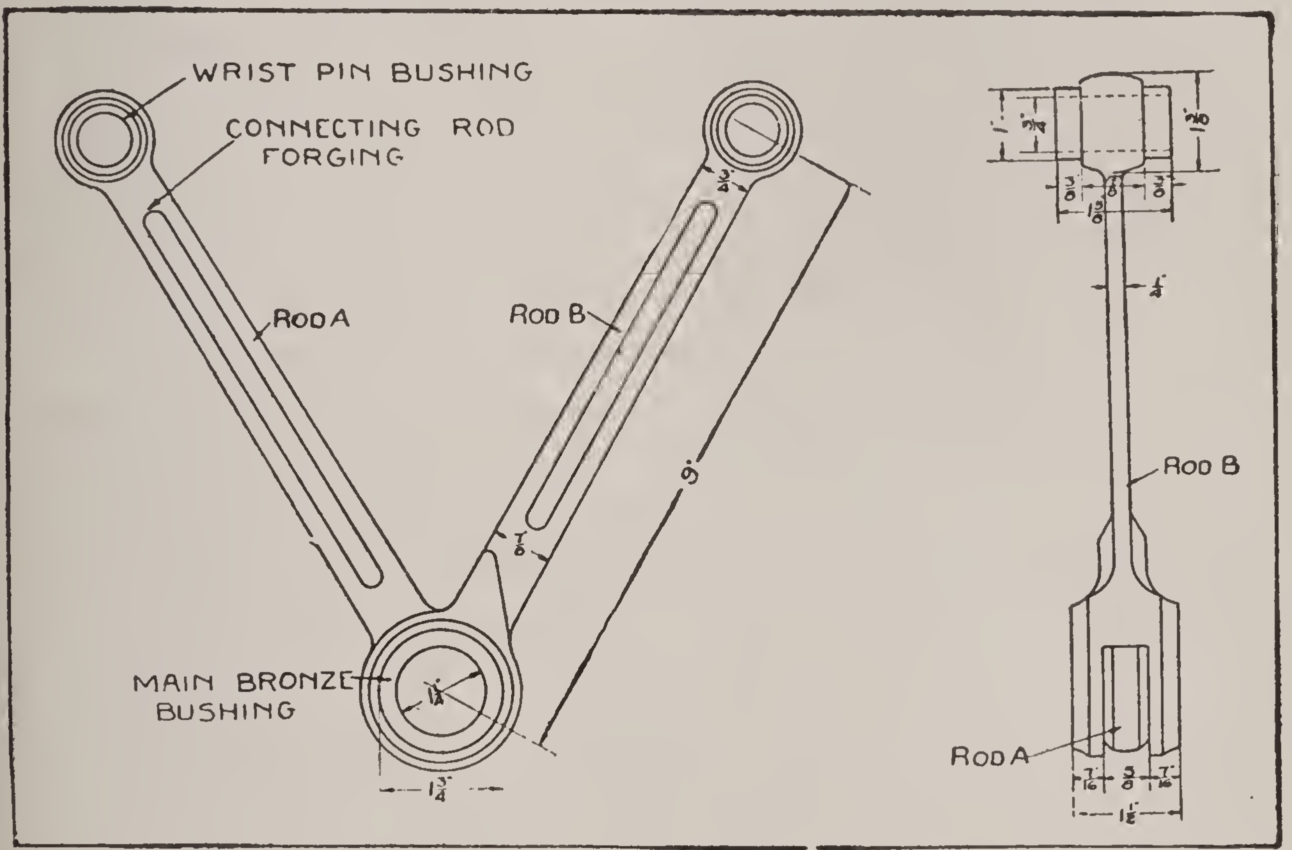


Fig. 113.—Usual Arrangement of Connecting Rods of Twin Cylinder Motorcycle Power Plant. This Working Drawing Gives the Principal Dimensions of an Assembly Used on a Nine Horse-power Motor.

The bearing metals are well selected in reference to the loads they are to carry and the bronze used has a high degree of resistance to deformation, and on the main bearing at least it is working in combination with a hardened steel crank-pin. Conditions are not so favorable at the forked oscillating bearing, however, as here the rod ends are comparatively soft where they bear against the outside surface of the bronze bushing. The value for safe working stress on crank-pin bearings is given as 1,280 pounds per square inch projected

area for hard steel and bronze in combination, and as 800 pounds per square inch for unhardened steel on bronze.

The main crank bushing of the connecting rod assembly at Fig. 113 bears against a hardened steel pin so the higher value applies, but the oscillating member, which is soft enough so it can be cut with a file bears against bronze, so the lower value must be used. The pistons used are 3½ inches bore, which means that the piston top area is 9.62 square inches. If we assume an explosion pressure of 300 pounds per square inch, which value may obtain at times in all power plants, this gives us a value of 2,886 pounds as the force of the explosion on the piston top. At a speed of 2,000 revolutions per minute, it should be considered that the main crank-pin bushing, which takes the explosion pressure of each cylinder is subjected to this force 2,000 times per minute as an explosion is obtained for each revolution, and both pistons must impart their pressure directly against the one crank-pin. We have seen that the projected area of the main crank-pin bushing is 1.87 square inches, so we can find the unit stress per square inch bearing surface by dividing the total pressure by the available projected area. This gives us a value of 1,543 pounds per square inch and shows that the main bearing would be overloaded nearly 300 pounds per square inch if only the explosion pressure was considered.

There are other loads on the bearing that must be added, one of these being the load due to centrifugal force of the rapidly rotating connecting-rod big ends as well as the inertia loads produced by the reciprocating members. To discuss these would be to complicate the discussion so that it would be difficult of comprehension by the average reader and it would serve no useful purpose because the load due to explosion pressure alone brings an overload on the bearings. Considering the load on the forked big end, we find that the projected area of 1.53 square inches is subjected to a load of 2,886 pounds at instant of explosion. This means a unit stress of 1,886 pounds per square inch on a bearing suited only for 800 pounds per square inch, and means an overload of 1,086 pounds or over 125 per cent.

This insufficient bearing area is obviously the reason for some of the trouble experienced with plain journals, as it is apparent that high unit pressures will squeeze the lubricant from between the sur-

faces and produce an actual metallic contact at times between bushing and crank-pin. The overload on the bearing is not serious enough to deform either bearing metal, but it certainly does promote cutting and scoring the bushing and crank-pin through the failure of lubrication. The lubricant forced from between the surfaces is thrown off of the rapidly revolving crank-pin by centrifugal force, and, unless new oil is supplied in a positive manner, the surfaces will be in actual metallic contact from time to time. Under the conditions outlined, it is not strange that plain bushings subjected to such severe service should depreciate rapidly.

The problem of main bearing design is not a serious one, as these can always be made sufficiently large, and there is no force tending to throw the oil out to any injurious degree when the fly-wheel assembly they support revolves. Another important point is that two bearings can be used to support the load that one crank-pin bushing of less than half their projected area must take. This condition alone is much more favorable to endurance, because the film of lubricant remains between crankshafts and bushings, and unit pressures are not high enough to squeeze it out.

Two forms of anti-friction bearings are used in connecting-rod big ends, and for crankshaft support. The roller bearing has advantages of moment in this application, but it has more friction than a properly applied ball bearing. The crank-pin, which is hardened and ground, forms an ideal surface for the bearing rollers to work on, and as the big end of the connecting rod can be hardened and ground very accurately a free running bearing can be obtained that will not be materially larger in diameter than a plain form, except for the difference in thickness between the bronze bushing and the roller members. The error commonly made is to make the rollers too small in diameter, and, while it is very desirable to keep the dimensions of the big end bearings down as much as possible, it is a harmful tendency when carried to extremes. Rollers are ordinarily about 3/8 inch in diameter, whereas, if proportioned in accord with the loads upon them, they should be 1/2 inch in diameter, at least.

If comparison is made between ball bearings and the rollers ordinarily used, it will be well to state that a roller bearing of sufficient capacity would be nearly as large, though some space would be saved

by the elimination of the outer race member needed with the ball bearing. The rollers bear directly against the metal of the connecting rod but the balls run in a separate hardened race member which has a groove of proper curvature for the balls to run in, and which is retained by the connecting rod big end. Either form indicated will give good service, though where the design permits, the most efficient bearing, which is the ball type, will prove more enduring.

The writer knows that considerable trouble obtained with the early ball bearings used for this purpose but in practically all cases, it could be ascribed to the desire to use bearings of small size, fostered to some extent by the wishes of designers more familiar with bicycle practice than with the requirements of self-propelled vehicles, and also to the competition between the manufacturers of such bearings. If one manufacturer recommended a larger bearing than a competitor, the business went to the maker selling at the lowest price, regardless of the merits of the bearing or its capacity for the work. The ultimate consumer was not the only one who suffered by this policy as the failure of such bearings reacted against the motorcycle builder, who promptly shifted the blame to the bearing manufacturer, who had to take it whether it belonged to him or not. This created the erroneous impression in some quarters that ball bearings were not as well suited to the work as roller bearings, whereas when properly selected and installed, these bearings answer all requirements besides running with minimum friction.

While a roller bearing is somewhat less in diameter than a ball bearing of the same capacity, it is wider and will contain nearly the same amount of metal. If the connecting rod big end wears it increases in bore, and either larger rollers or a new rod are needed. With a ball bearing, the outer race is an integral part of the bearing, it can be ground and fitted to the balls very accurately, as well as made of proper material. Ball bearing race members are usually of chrome steel, which has superior resistance while the drop forged rods are usually of a low carbon steel and must be carbonized at the bearing point, and treated before a sufficient degree of hardness can be obtained. With a ball bearing, the outer race is not only of proper stock treated independently, but the rod does not need other than a toughening treatment, if any, which does not call for carburizing.

While the writer does not mean to imply that roller bearings are wanting in reliability, or other features, out of justice to the ball bearing it is necessary to outline their advantages over the other types.

One of the conditions that has materially interfered with efficient ball bearing service has been the methods employed in installing them. A sectional view of the engine base of a power plant of European design is shown at Fig. 114, and this depicts the method of mounting

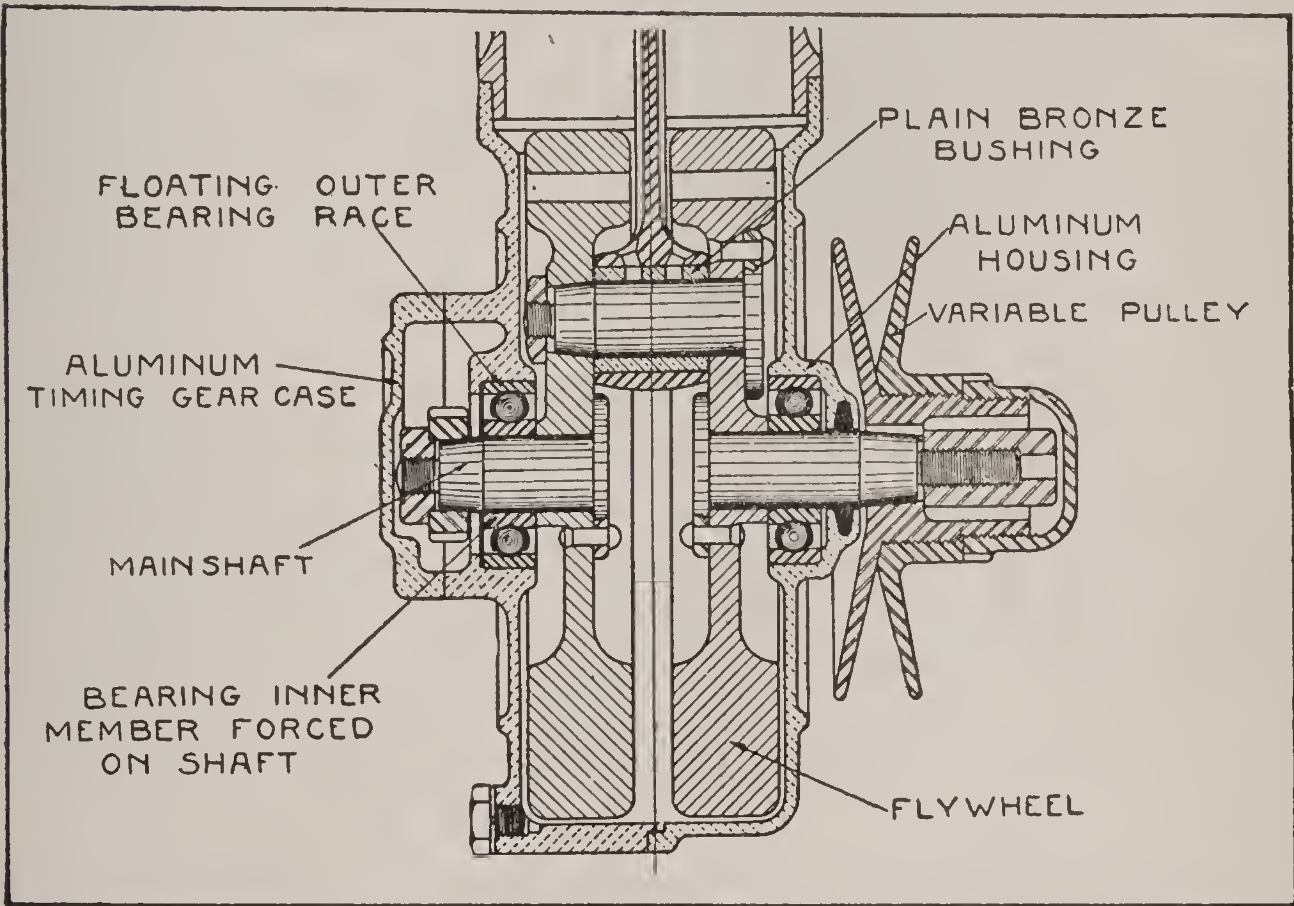


Fig. 114.—Sectional View of Crank Case, Showing Application of Single Row Ball Bearings in Supporting Flywheel Assembly.

usually employed. If the work of fitting is carefully done, the mounting will give satisfaction, though in the rush incidental to regular manufacturing, bearing inner race members are apt to be pushed on shafts machined a trifle small rather than forced on. The outer races rest directly in the housing of soft material, usually cast aluminum. While the bearing does not loosen up at once, still the constant succession of shocks due to explosion pressure tends to pein out the stressed metal supporting the outer race member. This enlargement

of the bearing housing permits the outer race to turn, and soon it is a very poor fit in the crank-case. The same applies to the inner race, which becomes loose on the shaft, so loose in fact, that the shaft will become scored and appreciably reduced in diameter. This condition is not exaggerated one iota, the crank-case of several ball bearing machines under the writer's observation have worn in just the manner indicated, and the bearing supporting shafts also.

Of course, bearings of standard bore and diameter cannot be used for replacement purposes, and the only remedy is to bush the housings with a steel or bronze member after it has been bored out enough to accommodate it, providing there is metal enough in the bearing housing walls. If the shaft is scored, it can be turned down enough to permit a steel bushing being forced on, this being machined so the outside diameter corresponds to the bearing bore. An alternate method, the more costly and satisfactory one, is to replace the defective members with new parts.

Installing the ball bearings in this manner is not the best practice, and no less an authority than Riebe, in a recent address before an engineering society, condemned the common practice as shown at Fig. 114, and advised the positive retention of bearing inner races by clamping members, as well as the housing of the outer races in bushings of harder material than the aluminum commonly used for crank and gear cases. As this engineer is one of the pioneers in the design of ball bearings, such advice cannot be passed by lightly.

The writer desires to submit a suggestion for the design of a twin-cylinder crank-case at Fig. 115, in which the bearing installation is on correct engineering lines as advised by leading authorities. To begin with, the design is different from that usually followed in that the cylinder centers are placed one to each side of the crank-case center line or in staggered relation. This point, no doubt is open to criticism, inasmuch as it makes for a slightly wider crank-case and more expensive construction. At the other hand, it would appear that if the front cylinder is set a little to one side, that the rear cylinder will receive some effect from the air draft created by cycle movement, and that more complete cooling will result. This placing of the cylinders independently of the crank-case center line makes it possible to use

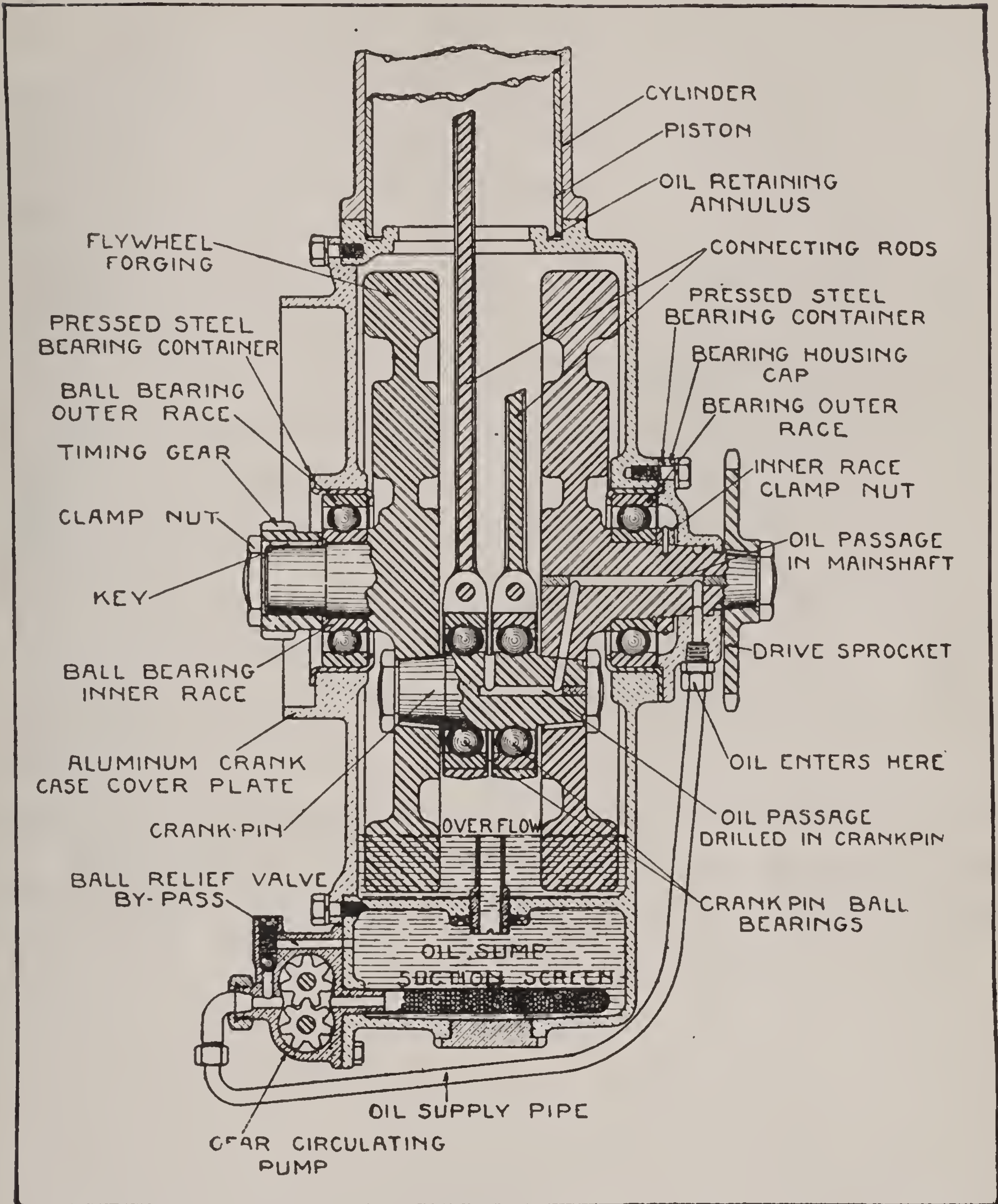


Fig. 115.—Design Drawing Showing Correct Application of Ball Bearings to Connecting Rod Big Ends as Well as Main Bearings of Twin Cylinder Motorcycle Power Plants. Note Automatic Lubrication System Provided.

ball bearings of correct proportions on the crank-pin, as each connecting rod has its independent anti-friction bearing.

The ball bearings are special in that they are assembled on the crank-pin, which takes the place of the bearing inner race members,

but as the balls, separators, outer races and even curvature of the inner ball races on the crank-pin conform to standard practice, such a bearing should not cost appreciably more than the regular standard product and a remarkable saving is effected in bearing diameter by forming the ball races on the crank-pin in the manner indicated. The outer races are kept from side movement by a clamping bolt passing through a slotted boss just above the bearing. As the outer race members may be ground within .0002 inch plus or minus, it will be apparent that but little bolt movement will suffice to hold the outer race firmly in place in connecting rod big ends.

Special attention is directed to the main bearings and the method of retention. Both are housed in supplementary pressed steel container, forced into the soft aluminum crank-case, these members of hard material resisting deformation due to alternate shock stresses much better than the softer alloy they protect. The bearing on the drive side has a clamped inner race, held tightly against a shoulder on the fly-wheel by a threaded clamping nut and the outer race, while not tightly clamped by the housing cap, is held so it will not have any more than .01 inch end movement. The inner race of the bearing at the timing gear end is clamped between shoulders on the fly-wheel shaft and timing gear, which member is firmly pressed against the inner race by the threaded retention nut. The outer race is allowed to float in its pressed steel container.

CHAPTER IV.

LUBRICATION, CARBURETION AND IGNITION.

Theory of Lubrication—Forms of Lubricants—Devices for Supplying Oil—Sight Drip Feeds—Simple Splash System with Hand-Pump—Mechanical Oilers—Lubricating Two-Cycle Engines—Motorcycle Fuel, Its Derivation and Use—How Fuel is Carried—Principles of Carburetion Outlined—What the Carburetor is for—Early Vaporizer Forms and Their Defects—Elements of Carburetor Design—Features of Automatic Carburetors—Typical Motorcycle Carburetors—Foreign Carburetor Designs—Methods of Carburetor Adjustment—Typical Mufflers and How They Operate—Use and Abuse of the Muffler Cut-out Valve—How Compressed Gas is Ignited—Parts of Simple Battery System—High Tension Magneto Action—Operation of Standard High Tension Magneto —Magneto Driving Means—Ignition Timing—Detection of Faults.

Theory of Lubrication.—All bearing surfaces, no matter how smooth they appear to be to the naked eye, have minute projections, and, when examined under a microscope, the surface of even a finely finished bearing appears rough. If bearings were run without oil, the microscopic projections on the shaft and on the bushing or box in which the shaft revolves would tend to interlock, and a great amount of friction would result. This would mean that much of the power developed by the engine would be utilized in overcoming this resistance. Without some means of minimizing this loss, considerable heat would be generated if the bearings were run dry, and, as a result, the overheated bearings would soon depreciate and would give signs of distress long before they failed by becoming firmly burned together.

The reason a lubricant is supplied to bearing points will be readily understood if one considers that the close-fitting surfaces of the shaft and bushings are separated by this elastic substance, which not only fills up the minute depressions, thus acting as a cushion, but which absorbs the heat generated by friction as well. In properly lubricated bearings, the oil takes all the wear that would otherwise come on the

metallic bearings. The grade of oil and amount to use depends entirely on the bearing points where it is to be applied. An oil that would be entirely suitable for lubricating the interior surfaces of the gas-engine cylinder would not be suitable for bearings in some cases if these were subjected to heavy pressures. At the other hand, the semi-fluid oil or grease which cushions the teeth of the driving and change speed gearing so well could not be used in the cylinders of the engine.

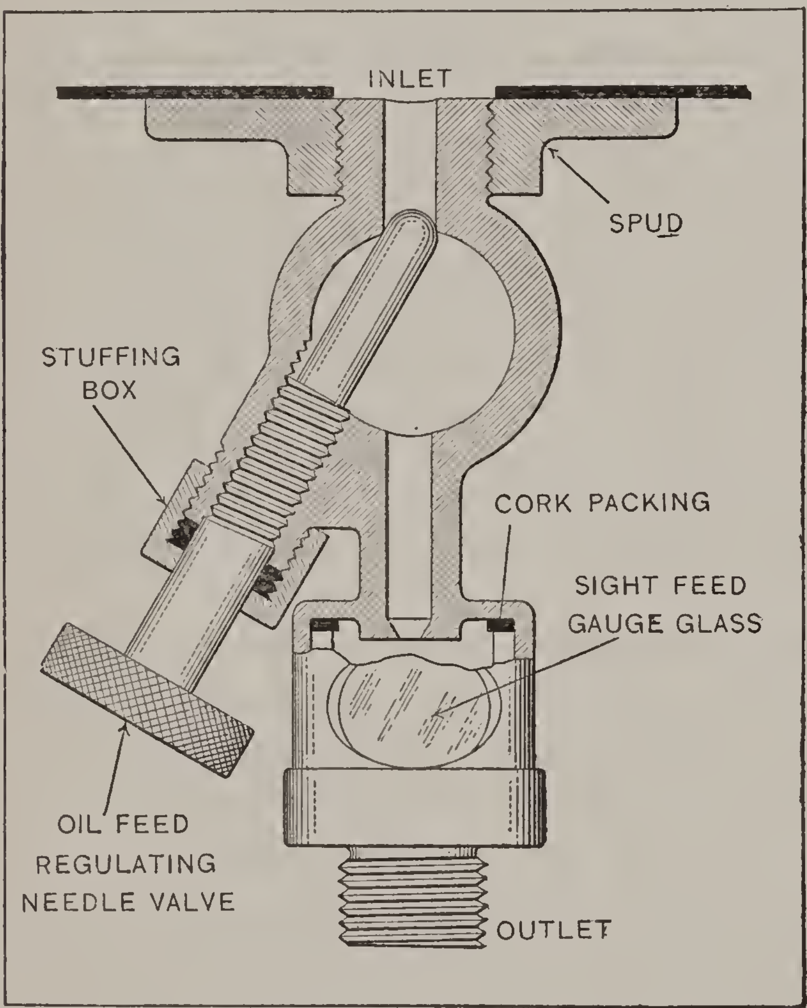


Fig. 116.—Diagram Showing Construction of Drip Feed Lubricator.

When used for air-cooled engine lubrication, an oil must be capable of withstanding considerable heat, in order that it will not be evaporated or decomposed by the hot metal of the cylinder. The oil used for cylinders or bearings should have a low cold test, i. e., it should not thicken up at low temperatures so that it will not flow freely. All authorities contend that lubricants must be free from acid which will corrode the metal surfaces to which the oil is applied. A lubricant must have sufficient body to prevent metallic contact of the parts between which it is depended upon to maintain a resilient film. It should not have too high a body or too much viscosity because a lubricant that is too thick will have considerable friction in itself, and will not flow readily between bearing surfaces.

If the lubricant is to be used in gearing where great cushioning qualities are desired in addition to positive lubrication, it must have

a heavy body and the semi-solid graphite greases are the best materials to use for this purpose. The grease or oil should also be free from injurious adulterants of either vegetable or animal origin, because these invariably contain fatty acids that will decompose and attack metal surfaces or gums which will coagulate or oxidize by exposure to air and retard the action of the bearings. The best lubricants for motorcycle use are derived from a crude petroleum base with the exception of graphite which is a form of pure carbon that is a good lubricating medium for certain purposes.

Forms of Lubricants.—Oils of organic origin, such as those obtained from animal fats or vegetable substances, will absorb oxygen from the atmosphere which may cause them to become rancid. As a rule, these oils have a very poor cold test, because they solidify at comparatively high temperatures. Their flashing point and fire test are also so low that they are not suitable at points where considerable heat exists, such as the interior of a gas engine. The only oil that is used to any extent in lubricating gas engines that is not derived from a petroleum base is castor oil, which is obtained by pressing the seeds of the castor plant. This has been used on high-speed racing motorcycle engines and on aeroplane power plants, where it is practically pushed right up past the piston and out of the combustion chamber with the exhaust gases, so fresh oil must be supplied all the time to replace that ejected from the engine. Obviously this method of oiling would not be considered economical, and would not be suitable on either business or pleasure automobiles or motorcycles.

Among the solid substances that have been used for lubrication to some extent may be mentioned tallow, which is obtained from the fat of certain animals, such as cattle and sheep, and graphite, which is a natural mineral product. Tallow is usually employed as a filler for some of the greases used in transmission gearing, but should never be utilized at points where it will be exposed to much heat, and even under these conditions pure mineral greases are to be preferred. Graphite is obtained commercially in two forms, the best known being flake graphite, where it exists in the form of small scales or minute sheets, and the deflocculated form, where the graphite has been ground or otherwise divided into a dust. It is usually mixed with oil of high viscosity and used in connection with lubrication of change speed

or power transmission gear parts, though it has been mixed with cylinder oil and applied to engine lubrication with some degree of success. Graphite is not affected by heat or cold, acids or alkali, and has a strong attraction for metal surfaces. It remains in place better than an oil, and, as it mixes readily with oils and greases, their efficiency for many applications is increased by its use.

Any oil that is to be used in the gasoline engines must be of high quality and for that reason the best grades are distilled in a vacuum so the light distillates will be separated at a much lower temperature than ordinary distilling practice permits. When distilled at the lower heat, the petroleum is not so apt to decompose and deposit free carbon. A suitable lubricant for gas-engine cylinders has a vaporizing point at about 200 deg. Fahr., a flash point of 430 deg. Fahr., and a fire test of about 600 deg. Fahr. Cylinder oil is one lubricant that must be purchased very carefully. A point to remember is that the best quality oils, which are the most efficient, can only be obtained by paying well for them. The few cents saved in using a cheap oil is not of much moment when compared to the repair bill that may accrue from its use. The cheap oil will not only deposit carbon very freely in the cylinder heads but is liable to gum up the piston rings and valves, and detract much from the smooth operation and power capacity of the motor.

Devices for Supplying Oil.—When the internal combustion engine was first evolved, the importance of adequate lubrication to secure efficient engine action was not as fully realized as it is at the present time. Practically all of the early forms of engines were slow acting and the problem of lubrication was not as serious as that which confronts the present-day designer of high-speed power plants. The earliest system of oil supply was by filling the crank-case to a certain level, and depending on the rotating parts to pick up the oil and throw it around the interior of the motor. Later, the sight feed devices that have been used for lubricating bearings of steam engines and other machinery were applied to the gasoline engine. These consisted essentially of a glass cup held in place between bronze castings to form the top and bottom of the oil container, respectively. The amount of oil supplied the bearing points was regulated by a suitable needle valve, and the oil supply could be observed through a small

glass window in the bottom of the cup, before it reached the interior of the engine. Modern practice calls for a positive supply of the lubricating medium by mechanical means and the most effective of the methods of lubrication now in use are those in which the operator is depended on only to keep the oil container filled up.

Sight Drip Feeds.—An example of the fitting employed to regulate the oil flow when the lubricant is supplied by gravity is clearly shown at Fig. 116. Fittings of substantially this design have received wide application on motorcycles. They are usually screwed directly into the bottom of the oil tank, and as that member is always carried higher than the engine, when included in the fuel container, the oil will tend to flow by its own weight. The device consists of a simple casting member carrying at its lower end a small chamber adapted to receive a sight feed gauge glass through which the oil feed may be readily observed. The pipe connecting the sight feed fitting to the engine base is attached directly to the bottom of the chamber carrying the gauge glass. The oil enters the device through the opening in the bottom of the tank, and the amount of flow can be regulated within a wide range by the use of the oil feed regulating needle valve which also serves as a shut-off valve when lubrication is not desired. The oil collects in the globular portion of the casting and drips through the constricted opening above the sight feed gauge glass.

Simple Splash System with Hand Pump.—While the customary manner of lubricating the first engines was by supplying the crank-case directly with oil, there were certain defects to this system that made it imperative to add some device for directing the oil to the engine base without need of the rider dismounting. On the earlier motorcycles, it was common practice to supply a small oil cup just below the oil tank that held a certain amount of lubricant. The arrangement was such that this cup could be filled from the main container, and the instructions of the manufacturers were usually explicit in stating that every eight or ten miles of average riding that it would be necessary for the rider to supply the engine base with another cup full of oil. This meant that it was necessary for the rider to dismount and fill the cup from the main tank before permitting its contents to flow to the engine interior. The next improvement to be made was the addition of a hand-operated plunger

pump to supply the oil, and this was usually placed convenient to the rider so it could be operated without stopping the machine. A popular location was directly at the side or in the interior of the oil container. This system of lubrication is used on a number of motorcycles, even at the present time, either alone or in combination with some form of a drip feed fitting.

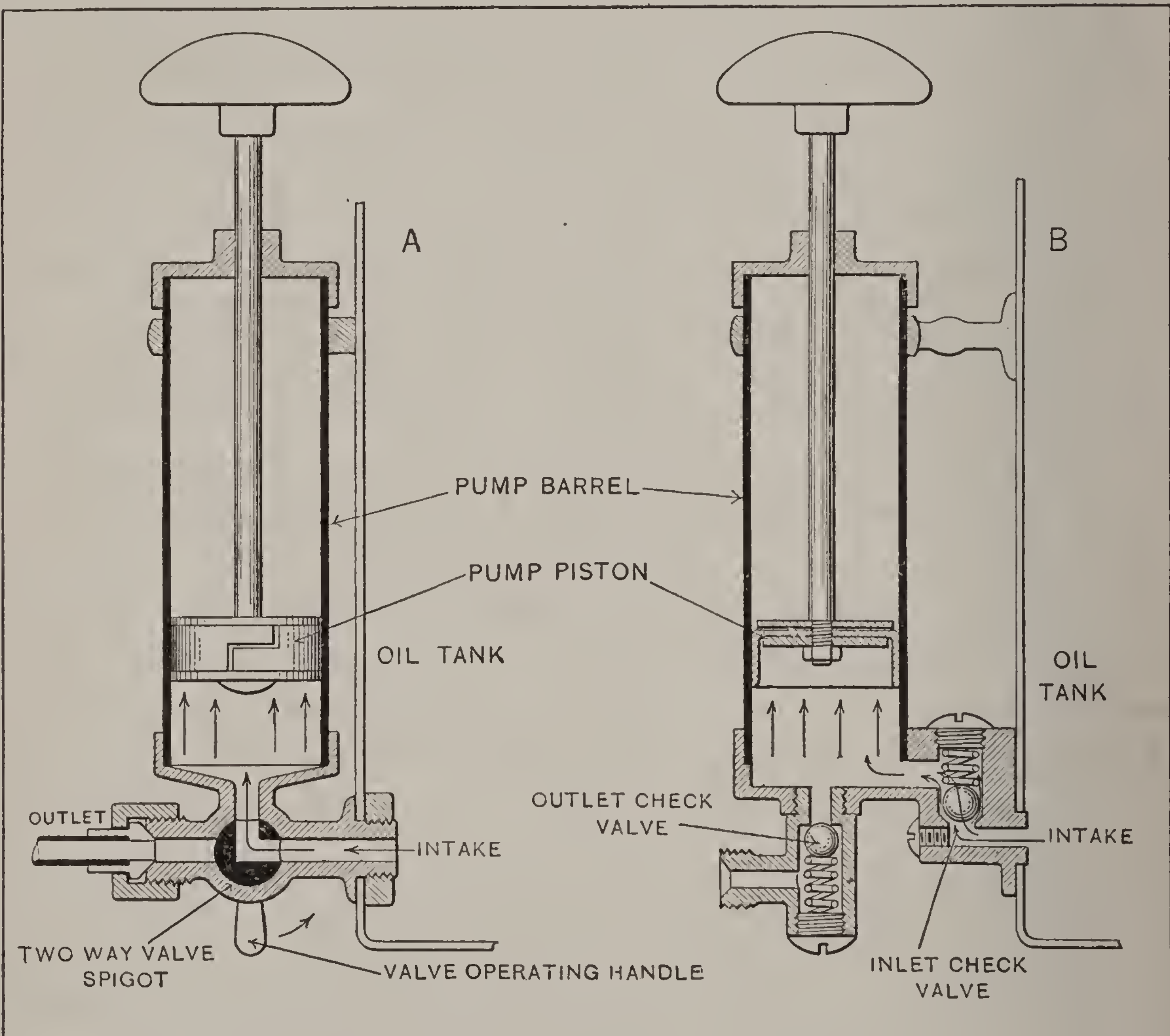


Fig. 117.—Types of Plunger Pumps Utilized in Forcing Oil to Engine Crank Case.

The plunger pumps are of two general types, as shown at Fig. 117. That outlined at *A* has manual control of the oil flow while that at *B* has automatic control. In the former, a two-way valve is provided in the bottom of the pump chamber, the spigot of which can be placed in three different positions. When placed as shown, with the valve operating handle pointing straight down, the interior of the pump is

directly in communication with the oil container, and an upward stroke of the plunger will fill the pump barrel or cylinder with lubricant. When the pump plunger is nearly to the top of its stroke, the valve-spigot operating handle is moved around in the direction of the arrow, so that it lies parallel with the intake passage. Under this condition, the two-way valve spigot was moved around so that the oil in the pump barrel may be forced through the outlet pipe because the oil tank is shut off by the solid wall of the spigot. If the valve-operating handle is turned a half revolution from the position assumed when discharging lubricant from the pump barrel, both orifices, that at the bottom of the pump, as well as the intake from the oil tank, are shut off, and no oil will flow either to the pump or to the engine until the valve-operating handle is moved as indicated. The arrows show the direction of flow of the oil when the pump piston ascends.

Another popular form of pump is shown at Fig. 117-*B*, and one reason for its popularity is that it is automatic in action, and requires no other attention on the part of the rider than raising and depressing the pump piston. When the pump piston moves upward, it creates a partial vacuum in the pump barrel, and this lifts the inlet-check valve from its seating and permits oil to flow into the pump interior. As soon as the pump cylinder is full, the inlet-check valve is reseated by a suitable spring, and, as the pump handle is moved down, the pressure of the oil tends to keep the intake check more firmly seated. The other check valve, however, is installed so it will open under the influence of the oil pressure, and this permits the lubricant to flow from the pump to the outlet pipe. The action of a pump of this nature may be easily understood by remembering that the intake-check valve will open only when the piston is going up, while the outlet-check valve will leave its seat only when the piston is going down.

Some trouble is apt to materialize in a pump of this character, owing to the check valves becoming clogged up by gum or wax in the oil, and if this occurs the pump will not operate satisfactorily. For this reason, the check valves are usually housed in such a way that they may be easily removed for cleaning. Those who favor the manually operated valve contend that the elimination of the check valve makes the action of the pump positive, and therefore best adapted to the requirements of the ordinary rider.

The oil injected into the engine base fills the crank-case to a certain height, as indicated at Fig. 118, and, as will be apparent, the revolving fly-wheel will pick up the lubricant and throw it about the interior of the engine liberally. The oil supply to the motor shown is by a hand-operated plunger pump which injects a charge directly to the

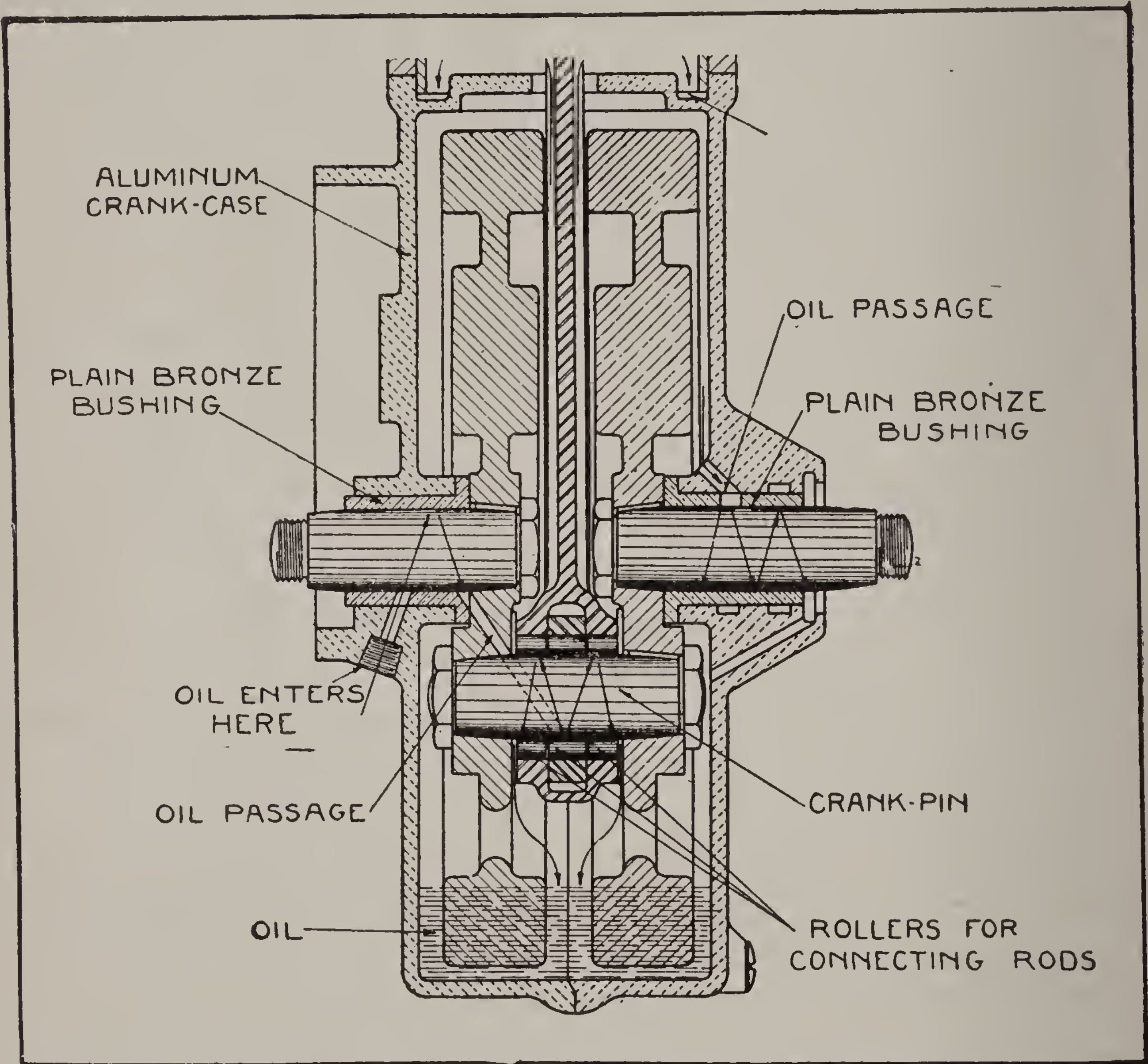


Fig. 118.—Application of Simple Splash System to Motorcycle Engine Lubrication.

crank-case as well as by a drip-valve fitting connected beneath the timing gear case.

This oiling system has given excellent satisfaction on a prominent machine, the Excelsior. Even though anti-friction bearings are used in the connecting rod big ends, every precaution has been taken to supply oil to the roller bearings in a positive manner. The lubricant

enters beneath the timing-gear case, and is directed to the main bearing shaft from which it is conducted to the crank-pin by a passage drilled in the fly-wheel web, and communicating with a similar passage in the crank-pin so the oil is discharged at the central point of the bearing. Before it can be thrown off by centrifugal force, it must lubricate the roller bearings at either side. The oil mist always present in the crank-case and cylinder interior lubricates the piston, cylinder walls and main bearings positively.

Mechanical Oilers.—The problem of gas engine lubrication has always been a vital one when plain bearings are used, and, while the simple splash system has the advantage of lack of complication, the motor is always operating in a state of either feast or famine as regards lubrication of parts. Main shaft bearings, cylinders, and all reciprocating parts will receive plenty of oil by the splash system, providing the oil level is high enough so the fly-wheels will pick up the lubricant as they rotate. The connecting rod big ends, which are attached to a rotating member, and one that turns very fast at that, cannot receive adequate quantities of oil because they throw it off as fast as it collects between the surfaces, except in some engines where the oil is supplied to the connecting rod big ends first. The writer does not mean to imply that the rod ends do not get oil, but from the way they wear out and the condition of the surfaces, it is apparent that they do not get enough oil at all times. Then again, when one considers that this is the bearing that takes the greatest stress, and that the projected area of the bushing is seldom conducive to maintenance of an oil film, it is not strange that anti-friction bearings are being used so generally to replace big end plain bushings.

One of the first lessons learned by automobile engineers was that oil must be supplied in a positive manner if connecting-rod bushings were to endure, so in all automobile engines designed for racing or other exacting work and in most pleasure cars, force-feed lubricating systems are employed, and the lubricant is directed to the bearings through passages in the crankshaft by pressure produced by some positively driven force pump. If this precaution is considered desirable on automobile power plants, where bearing surfaces do not need to be restricted in size, and which operate at about half the speed of a motorcycle engine, then it is apparent that positive lubrication is

not only very desirable but indispensable in small, high-speed engines of the air-cooled forms used to propel motorcycles.

The oil pump used on the Indian motorcycle, and the method of application are clearly outlined at Fig. 119. The phantom view shows the simplicity of the pump mechanism very clearly, as well as defining the method of reciprocating the plunger. A small worm gear is driven

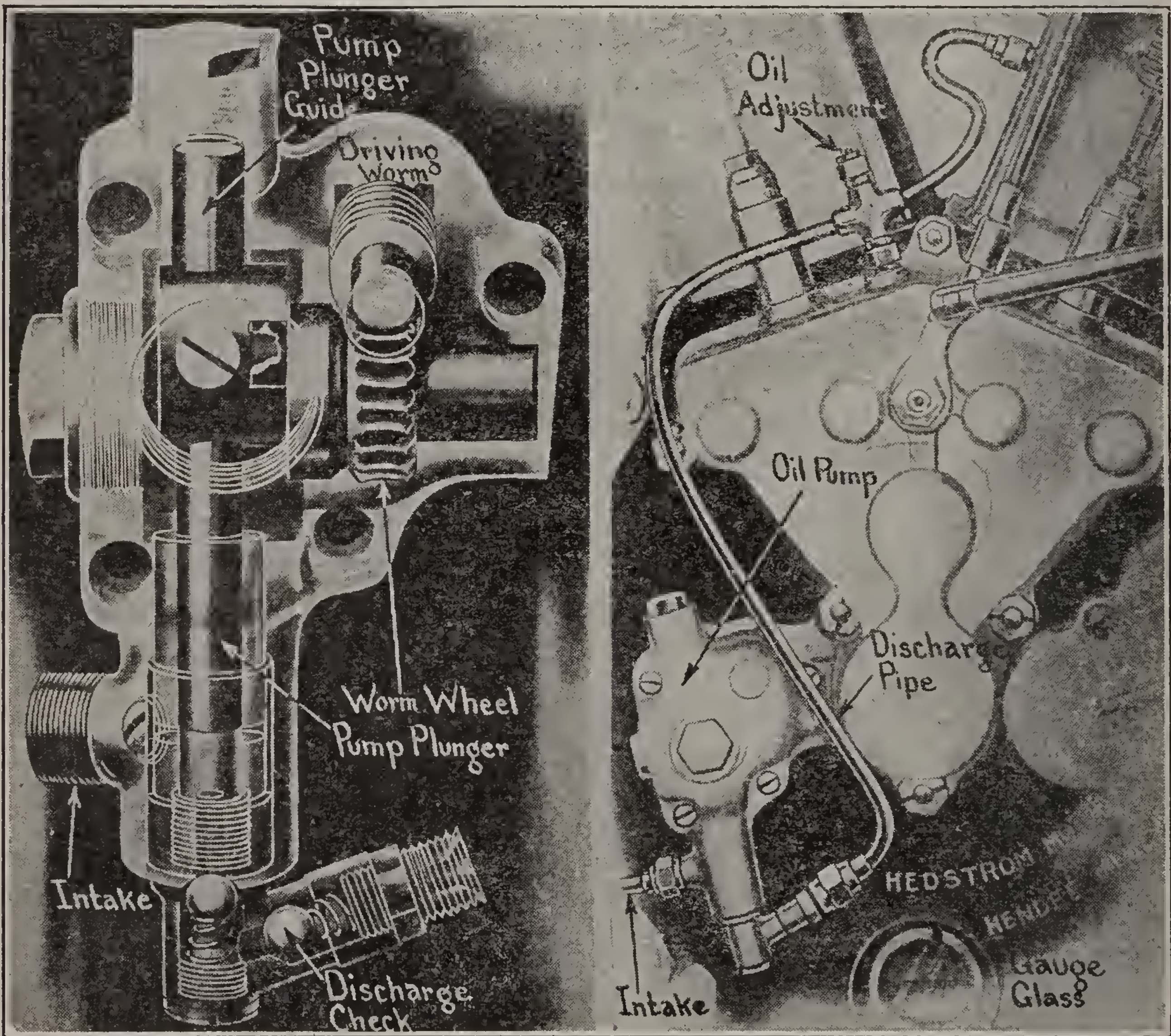


Fig. 119.—Mechanical Oil Pump Used on the Indian Motorcycles and Method of Application to the Power Plant.

from the timing gear, through the medium of a small spur pinion on the end of the driving worm shaft that projects into the engine interior. This worm rotates a worm wheel that works the crank employed to reciprocate the pump plunger. As the pump plunger is raised, oil flows in to fill the barrel through the intake which is coupled directly to the tank, and on the down stroke the oil is discharged

through the outlet-check valves to the front cylinder, from which it drips into the interior of the engine. The oil level in the engine base can be readily ascertained by a gauge glass or window in the side of the crank-case. The oil is supplied to the front cylinder to insure that that member will receive an adequate supply. The tendency of the fly-wheels as they rotate is to throw the oil into the rear cylinder

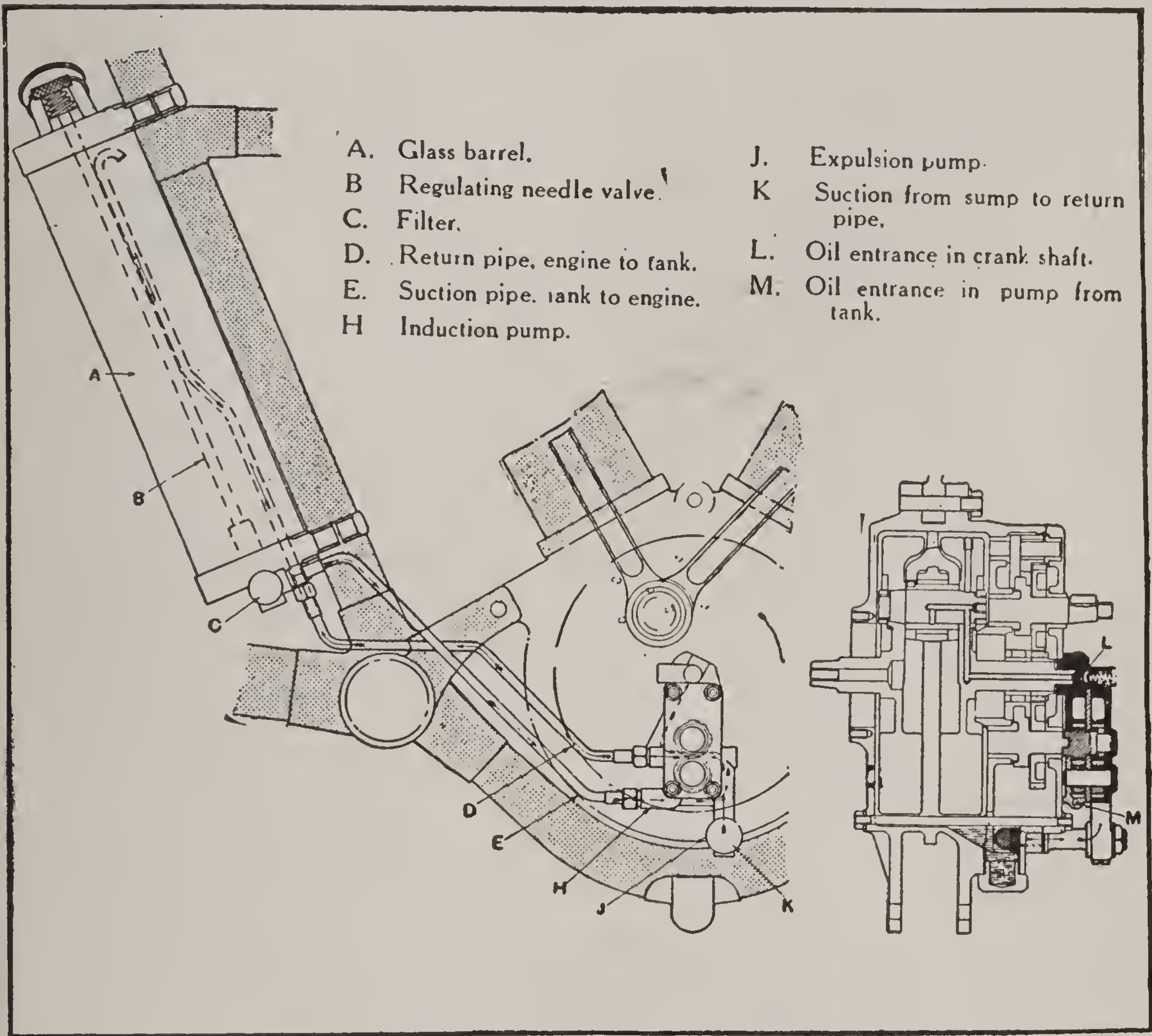


Fig. 120.—Lubricating System Employed in the Royal Enfield Motorcycle.

rather than the front one, because that member is approximately in line with the oil spray as it is discharged tangentially from the rapidly revolving fly-wheel rim. This would result in the rear cylinder securing better lubrication than the front one if no provision was made for directing the oil from the mechanical pump to the front cylinder. In most cases, a mechanical oil pump is supplemented by a hand-operated

type which is used in emergencies when it is necessary to supply more lubricant than the pump will deliver, as in fast riding.

The oiling system of a prominent English machine, the Royal Enfield, is outlined at Fig. 120. The oil is carried in the tank at the back of the seat-post tube, and one of two pumps fitted outside of the timing-gear case draws the lubricant from the tank to the engine. The second pump, called the expulsion member, forces the oil from the engine base back again into the tank. Obviously, as long as the engine is running, there is a continuous circulation of oil. The diagram clearly outlines the whole system and the path followed by the oil from the tank A to the engine and back again. The supply of lubricant is regulated by a needle valve B which has a knurled top, and from that point passes through a filter C along the suction pipe E to the induction pump H. This pump discharges into the hollow end of the crankshaft L, forcing the oil along this shaft through an aperture in the fly-wheel, into the crank-pin bearing, from which point it is distributed by centrifugal force to the other engine parts. The oil then drips back into a sump integral with the crank-case, and any excess which has not passed through the engine shaft also reaches this sump through a by-pass or release valve. The expulsion pump J draws the oil from the sump K and passes it back again to the tank through the return pipe D. A filter in the sump retains any residue contained in the oil, and insures that only clean lubricant will be pumped back into the tank.

The lubricating system used in the four-cylinder Pierce motorcycle is somewhat similar, except that but one pump is utilized instead of two. This system is clearly shown at Fig. 121. The oil flows by gravity to the base of the crank-case, from an oil tank forming part of the large front frame tube, and passes through the working parts as it flows. This flow is rapid and is started when a valve at the top of the tank is given a quarter turn. As soon as the engine starts, a rotary pump of the gear type sucks the oil from the oil well or sump at the bottom of the crank-case and forces it through a discharge manifold into chambers in which the lower ends of the connecting rod dip. With this system it is necessary to shut off the flow of oil at the tank whenever the machine is stopped, in order to prevent flooding the motor.

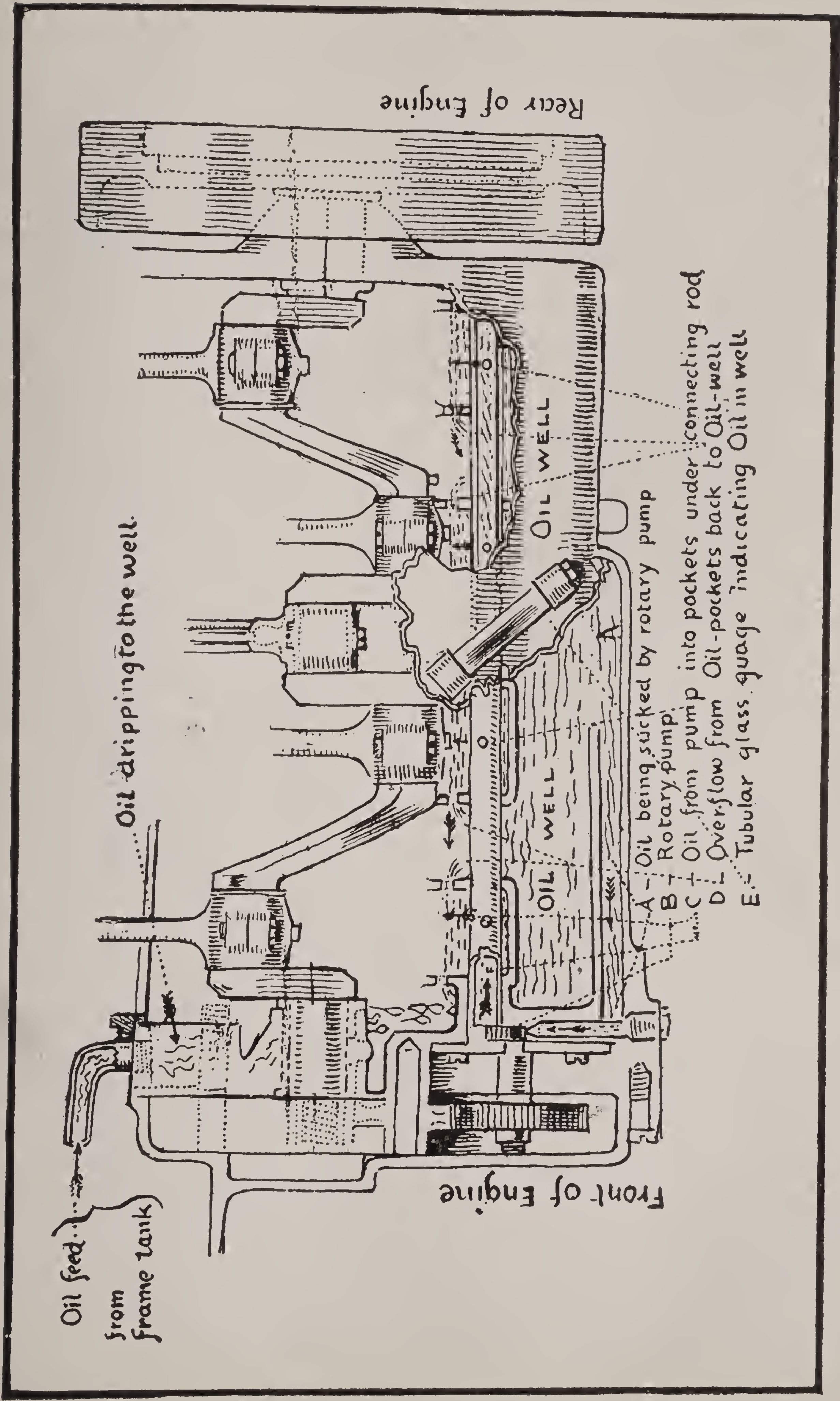


Fig. 121.—Lubricating System Used in Pierce Four Cylinder Motorcycle Power Plant.

A modification of this system is shown at Fig. 122 applied to a single-cylinder engine. The usual form of pump drive by spiral gears is employed to draw oil from the container or sump integral with the engine base, but it is discharged from the oil supply pipe into a passageway that communicates with the interior of a hollow crank-pin. From here, it passes through an oil tube attached to the connecting rod and lubricates the wrist pin. The oil thrown from the rapidly revolving fly-wheel lubricates the cylinder and piston walls thoroughly.

The lubrication system outlined at Fig. 115 insures that the bearings will receive copious oiling and is a form that has given excellent service on thousands of automobiles, as well as having been successfully applied to four-cylinder motorcycle engines. The pump draws oil from a sump cast integral with the crank-case through a filter screen. The oil level in the crank-case proper is kept at a certain predetermined height by an adjustable overflow pipe so the fly-wheels will pick up lubricant as they revolve, as in conventional systems. The advantage of the adjustable overflow is that this can be easily changed at any time to permit of more or less oil in the crank-case. For example, if the engine is to be run at high speeds, as in racing, the level can be made higher. When the machine is new, or after new rings have been fitted to the piston, it may also be desirable to furnish more oil than would be required under normal operating conditions. The standpipe adjustment can be readily altered to suit conditions.

The gear pump discharges the lubricant at some pressure and this is piped to a point at the bottom of the bearing housing cap at the drive side, where it communicates with a groove in the crankshaft. This groove is connected to a drilled passage in the shaft by another hole drilled at right angles to that in the shaft. The passage extends through the fly-wheel to the crank-pin center, from which a discharge hole directs the oil to a point between the crank-pin ball bearing races. The centrifugal force assists in distributing the lubricant, and the crank-pin bearings receive all they need. The oil spray thrown off by the revolving crank-pin supplements that picked up by the fly-wheels, and all interior parts receive positive lubrication. As the oil may be kept to the correct level automatically to insure adequate lubrication by splash, the rider's responsibility ceases when he has

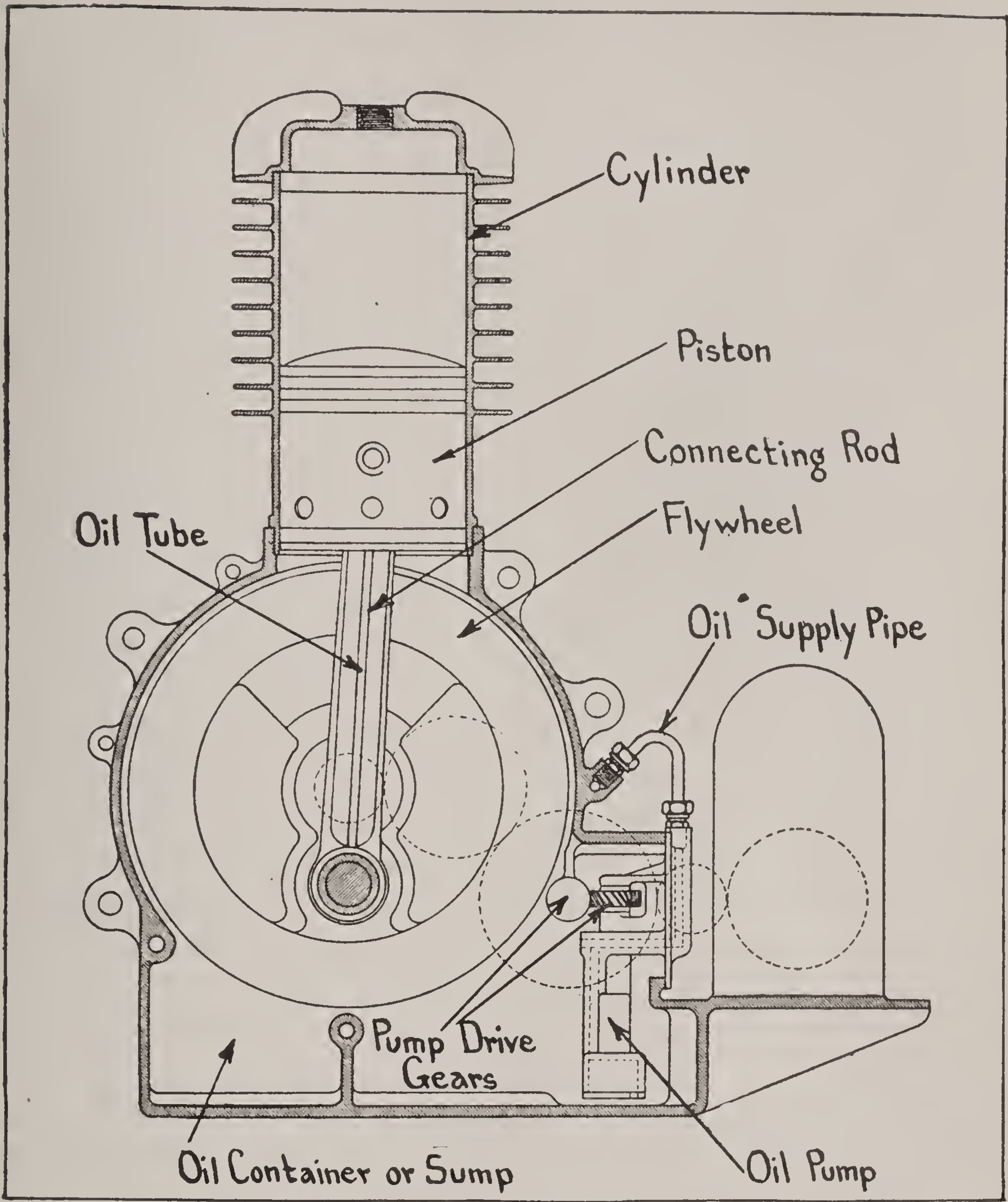


Fig. 122.—Mechanical Oiling System Applied to Single Cylinder Motor.

placed sufficient good oil in the sump. He may even be relieved of this duty by having an oil tank attached to the sump in such a manner that oil will be automatically supplied by the air lock system.

Lubricating Two-Cycle Engines.—An advantage of some moment that is obtained by the use of a two-stroke power plant is the very simple method of lubrication employed in which all pumps,

sight feed or drip devices and piping may be eliminated. The method of supplying the lubricant consists merely of mixing a certain amount of oil with the gasoline by pouring it directly into the gasoline tank. Owing to the construction of a two-cycle motor, which decrees that the explosive mixture must go into the engine base before it can pass into the cylinder it is possible to supply oil in the manner indicated. The oil is not dissolved by the gasoline but still its viscosity or body is reduced to such a point that it will pass through the spray nozzle of the carburetor without any difficulty. It separates from the explosive vapor in the engine base and condenses in the form of minute globules of oil on all interior parts of the engine. A certain amount of the condensing oil vapor finds its way to the bottom of the engine crank-case, and is distributed by the fly-wheel just as in other splash systems. The amount of oil used is approximately one-half pint per gallon of gasoline, i. e., if two gallons of gasoline were poured into the fuel tank, it would be necessary to add a pint of oil to insure that the engine would be adequately lubricated. The proportion may also be expressed as, one part of oil to sixteen parts of gasoline by volume.

Attempts have been made to lubricate four-cycle engines in this manner, but have not been successful on account of the mixture being supplied directly to the cylinder interior instead of to the engine base. The oil deposited in the combustion chamber interfered materially with correct valve action and promoted carbonization and caused ignition trouble by short-circuiting the spark plugs. In the two-cycle motors, the oil is well separated from the mixture before the gas charge is transferred to the cylinder interior from the crank-case.

Motorcycle Fuel, Its Derivation and Use.—The great advance of the internal combustion motor can be attributed more to the discovery of suitable liquid fuel than to any other factor. The first gas engines made, utilized ordinary illuminating gas as a fuel, and, while this is practical for use with stationary power plants, wherever it is available, such as the natural gas fields of the Middle West, or in cities and towns having a central gas producing plant, it is obvious that it could not be very well applied to portable self-propelling power plants used for cycle propulsion. When it was discovered that certain of the liquid fuels belonging to the hydro-carbon class, which includes petroleum and its distillates, benzol and benzene, which are coal tar

products and alcohol, could be carbureted or mixed with air to form an explosive gas, the gas engine became widely used as a prime mover for all classes of vehicles.

The liquid fuels have the important advantage that a quantity sufficient for an extended period of engine operation can be easily carried in a container that will not tax the capacity of the engine, and that requires but comparatively little space in any out-of-the-way portion of the frame. When used in connection with a simple vaporizing device, which mixes the liquid with sufficient quantities of air to form an inflammable gas, the fuel is automatically supplied to the engine without any attention being demanded from the operator as long as the supply in the tank is sufficient to produce a flow of liquid through the pipe joining the mixing device and fuel container.

Up to date, the most important fuel used in connection with motorcycle and automobile engines has been one of the distillates of crude petroleum, known generally to the trade as "gasoline." This liquid, which is a clear white, very light-bodied substance, evaporates very rapidly at ordinary temperatures. This feature made it especially adaptable for use with the early forms of mixing valves, because it mixed so readily with air to form an explosive gas. Fifteen years ago, there were very few industrial uses for gasoline and it sold for less than five cents a gallon in some cases. During the past decade, the demand for it has increased by leaps and bounds, and it now sells for four times as much as it did when the gasoline engine was first introduced.

The specific gravity of gasoline varies from sixty to seventy-six degrees, though very little of the latter is now obtainable except by special arrangement with the oil-producing company. It was formerly thought that gasoline any heavier than seventy-six degrees would not work satisfactorily in the cylinders of the gas engine, and, while this is true of the early crude and inefficient vaporizers, modern mixing devices have been evolved which handle gasoline of sixty-two degrees specific gravity and even heavier. The percentage of gasoline produced from crude oil in proportion to the other elements is very small, and as the demand has increased to such proportions, the tendency of the producer has been to make gasoline heavier or of lower specific

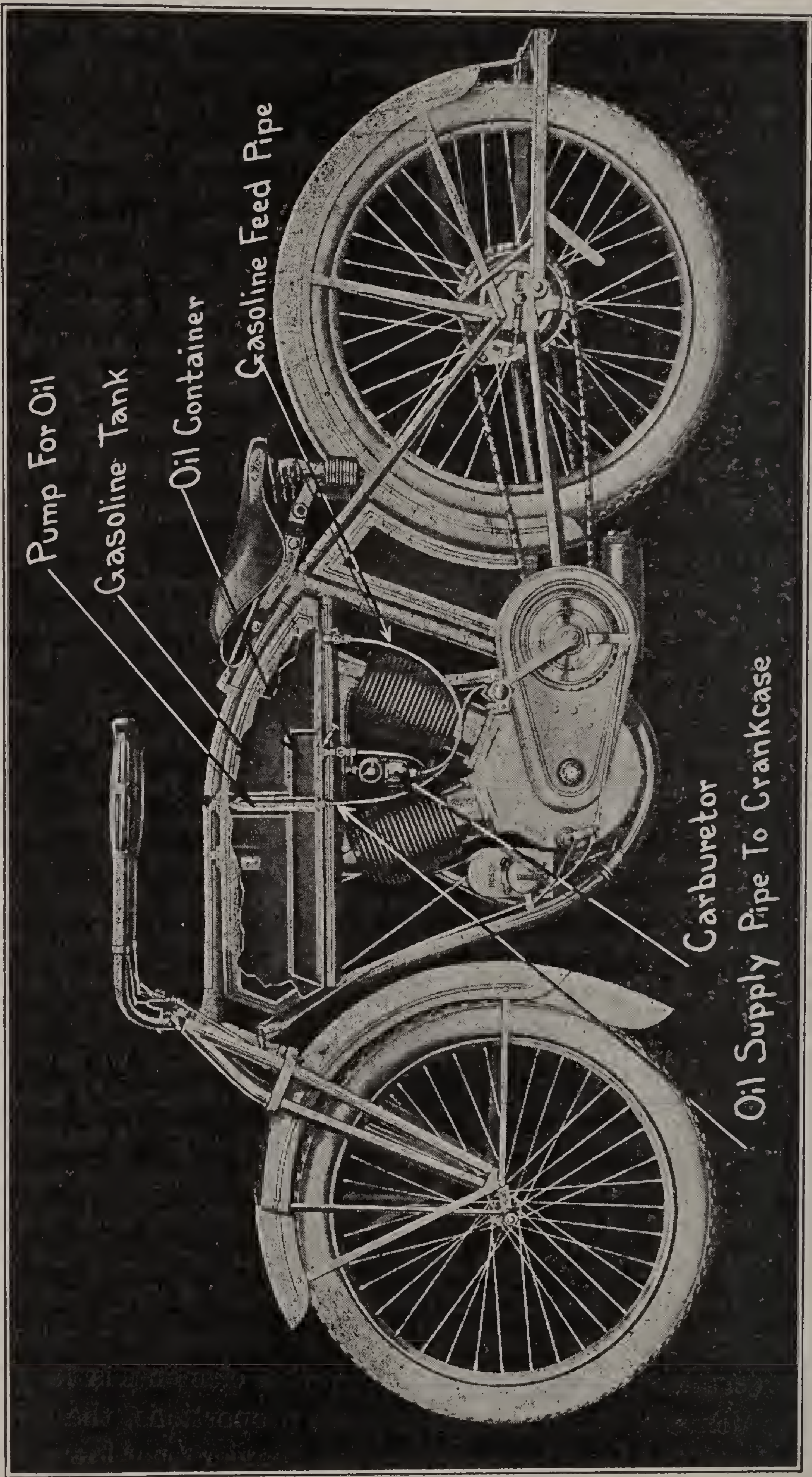


Fig. 123.—Showing Location of Fuel and Oil Containers on the Eagle Motorcycle. This Arrangement is Representative of Standard Practice.

gravity by distilling off some of the heavier oils with it to increase the bulk produced.

Experiments are being tried with kerosene and alcohol in automobile carburetors, but these fuels are not considered seriously in connection with the motorcycle, on account of the small fuel consumption of all motorcycle power plants. When a gallon of gasoline will suffice for 50 or 60 miles' travel, fuel expense is not a serious item, even considering the present price of gasoline.

How Fuel is Carried.—The conventional method of carrying both the fuel and lubricating oil is clearly shown at Fig. 123, which gives a view of the Eagle motorcycle with the side of the tank broken away to show its division into two parts. The larger portion serves as a container for gasoline and is connected directly to the float chamber of the carburetor by the gasoline feed pipe. The oil container also houses the plunger pump used to supply oil directly to the crank-case and is provided at the bottom with a drip feed of the type previously described. The location of the motorcycle fuel tank is practically the same on all machines at the present time, though in the early days, as can be very clearly understood by referring to the views of pioneer forms of motorcycles given in the first chapter, it was attached to the frame at any convenient point. The popular location was overhanging the rear wheel. At the present time, the tank is invariably placed above the motor, and, while most makers favor the detachable construction by which a removable tank is placed between the top frame tubes, some manufacturers incorporate the tank as part of the frame structure. This is true of the Schickel motorcycle, in which the tank is an aluminum casting that also has the steering head and suitable projecting lugs for anchorage of the frame tubes cast integral. In the Pierce motorcycle, the frame is made of large tubing, and this serves to contain the fuel and lubricating oil as well as forming the frame structure. While the fuel tanks are usually made of steel, they are either galvanized or copper or brass plated in the interior to prevent corrosion due to moisture or acids in the gasoline. The endeavor of most designers is to attach the tank to the frame in a positive manner, and yet have the tank retaining brackets or clips accessible so that member can be easily removed for repair if it becomes damaged. The best material for tanks is heavy gauge copper as it is easier to solder

than steel, and is not affected by moisture or other agents that would have a chemical action on steel.

Principles of Carburetion Outlined.—Carburetion is a process of combining the volatile vapors evaporating from the hydrocarbons previously mentioned with enough air to form an inflammable gas. The amount of air needed varies with the character of the liquid fuel and some mixtures burn much quicker than others. If the fuel and air mixture is not properly proportioned, the rate of burning will vary, and either an excess of fuel or air will reduce the power obtained from combustion materially. The proportions of air and liquid needed vary according to the chemical composition of the liquid.

Gasoline, which is that commonly used at the present time, is said to comprise 84 per cent carbon and 16 per cent hydrogen. Oxygen and nitrogen form the main elements of the air, and the former has a great attraction for the main constituents of hydrocarbon liquids. What we call an explosion is merely an indication that the oxygen of the air has combined chemically with the carbon and hydrogen of gasoline. In figuring the proper amount of air to mix with a given quantity of fuel one takes into account the fact that eight pounds of oxygen are required to burn one pound of hydrogen, and that two and one-third pounds of oxygen are necessary to insure the combustion of one pound of carbon. As air is composed of one part of oxygen and three and one-half portions of nitrogen by weight, for each pound of oxygen one needs to burn either hydrogen or carbon, four and one-half pounds of air must be allowed. About sixteen pounds of air must be furnished to insure combustion of one pound of gasoline, the hydrogen constituent requiring six pounds of air, while the carbon component needs ten pounds of air.

Air is not usually considered as having much weight, but at a temperature of 62 deg. Fahr. fourteen cubic feet of air will weigh a pound. Two hundred cubic feet of air will be needed to burn a pound of gasoline according to theoretical considerations. The element nitrogen, which is the main constituent of air, is a deterrent to burning as it does not aid combustion or burn itself. Therefore, it is usual practice to provide four hundred cubic feet of air to each pound of gasoline. Mixtures varying from one part of gasoline vapor to from four to thirteen parts of air can be ignited, but the best

results are obtained when five to seven parts of air are combined with one of gasoline vapor. This mixture produces the most rapid combustion, the highest temperature, and, consequently, the most pressure.

What the Carburetor is for.—Any device which will supply gasoline and air in measured quantities so inflammable mixtures of the proper proportions will be supplied the engine is called a "carburetor." In its simplest form, a carburetor would consist of a pipe open at one end for the admission of air, and joined to the cylinder at the other, and having a spray nozzle or opening through which gasoline could be injected into the air stream placed at some intermediate point in the pipe between the air inlet and the gas outlet to the cylinder.

Early Vaporizer Forms.—The surface carburetor was the first device to be used in combining air with gasoline to form an explosive vapor. Before the motorcycle or automobile became popular, the gasoline available was of very high volatility, i. e., it evaporated much more readily than the heavier fuels available to-day. A typical surface carburetor, such as used on one of the earliest practical motorcycles, the Wolfmueller, is shown at Fig. 124. The operation of this device is easily understood. The carburetor was filled with fuel to a definite height which was so regulated that the surface of the liquid was just below the lower main air pipe opening. The air entered through a funnel-shaped member which deflected it over the surface of the fuel. Here it became mixed with the vapor given off by the volatile liquid and the mixture passed through a safety screen to a mixing valve on top of the carburetor. The vapor given off was very rich, and, in order to dilute it, extra air was admitted through an auxiliary air cone attached to the mixing valve. The gas supply to the engine was regulated by a simple throttle as was also the amount of air from the auxiliary air entrance. A separate throttle was provided to regulate the quantity of gas supplied as the only function of the mixing valve or chamber was to regulate the quality of the gas.

Another form of surface carburetor that received wide application on the early motor tricycles of De Dion-Bouton manufacture is outlined at Fig. 125, A. In action, it is very similar to that previously described, except that it was improved in some details. For example,

a plate was attached to the bottom of the main air supply tube, and this insured that all the air currents would pass over the surface of the liquid and become saturated with vapor. It was necessary to use a mixing valve at the top of this carburetor, in order to dilute the rich vapor, so as to secure an explosive mixture of proper proportions.

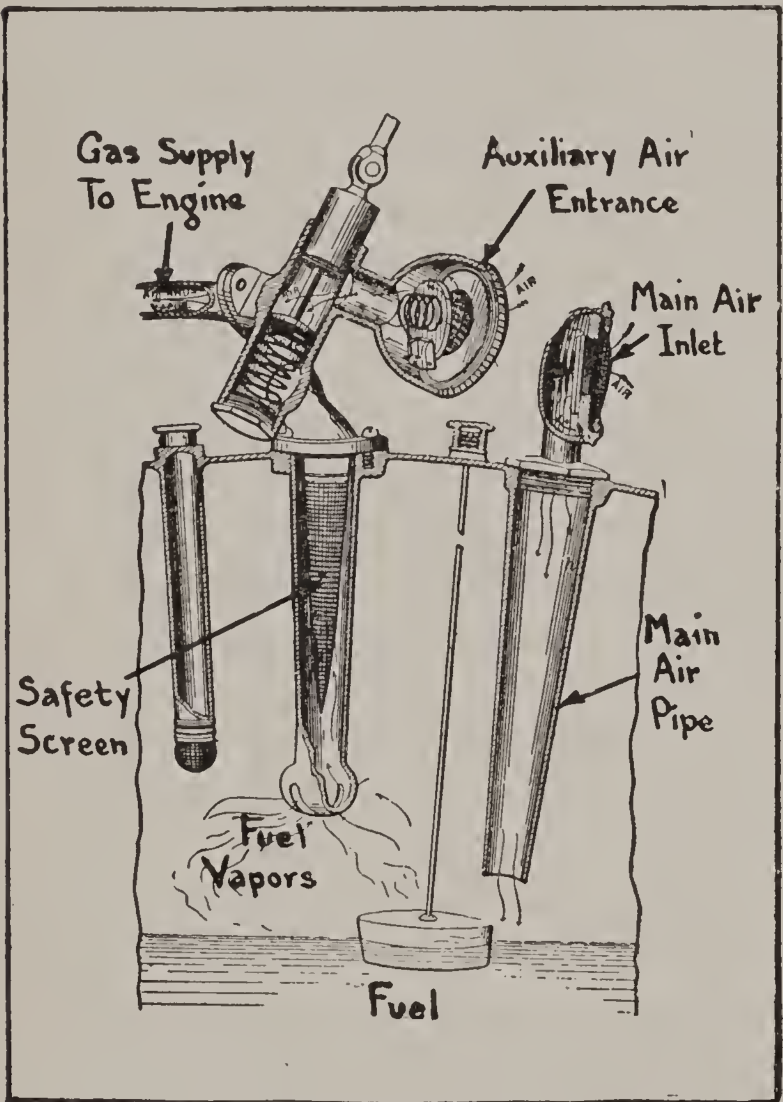


Fig. 124.—The Wolfmueller Surface Vaporizer, One of the First Practical Devices for Carbureting Volatile Hydrocarbons.

The simple form that is really the parent of our present float feed carburetors is shown at Fig. 125, B. In this, the gasoline was supplied from a container to a fuel inlet on the side of the main casting. A regulating needle valve was placed in the passage that provided communication from the fuel inlet to the jump valve seat. The air entered below the jump valve which was normally spring retained against the seating so that the mixing device was divided into two parts, one below, the other above the valve. As the valve covered the spray opening, no gasoline could flow into the mixing device as long as the valve was held against its seat by the spring. The suction of the piston in the engine cylinder raised the jump valve from its seat, and at the same time the partial vacuum caused the gasoline to spray out of the opening and mix with the current of air drawn in through the main air inlet and into the upper portion or mixing chamber of the device. The amount of liquid supplied the mixture was regulated by the needle valve, while the proportion of

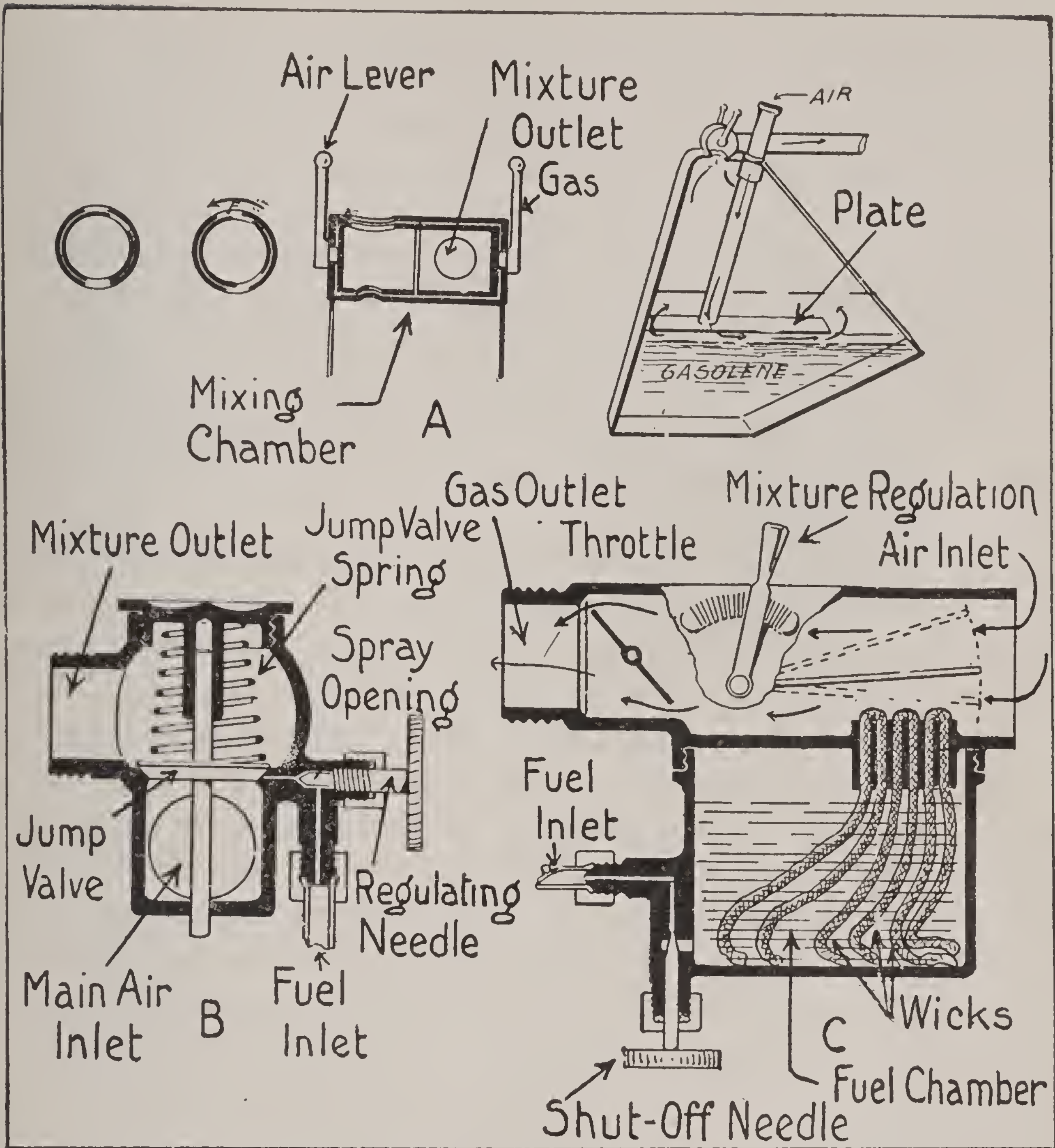


Fig. 125.—Early Types of Gasoline Carburetors. A—De Dion Bouton Surface Vaporizer. B—Simple Spraying Device With Automatic Jump Valve. C—Diagram of Wick Carburetor.

air could be altered at will by limiting the movement of the jump valve.

A third form that received limited application is known as "the wick feed carburetor," and is illustrated at C, Fig. 125. In this device, the liquid was drawn to the top of the container by the capillary attraction of the wicks, and as the top of these were brushed over by the main air current, the vapors given off were mixed with it to form an explosive gas. The mixture proportions were regulated

by a simple shutter which could be swung on an arc so that it could be brought very close to the wicks or moved away. This shutter deflected the entering main air current against the wicking, and when in its uppermost position, practically no air would enter the mixture without passing over the surface of the wicks and becoming saturated with fuel vapor. When the shutter was in an intermediate position, part of the entering air stream would pass over the wicks while the remaining portion would flow directly into the column of gas and dilute it if too rich. The fuel inlet from the tank to the fuel chamber of the mixing device was controlled by a shut-off needle and the amount of mixture supplied the engine could be varied by a simple throttle of the damper type.

Defects of Simple Vaporizer Forms.—The simple mixing valve forms have disadvantages of some moment, the main defect being that they are somewhat erratic in action, and that the mixture cannot be as well regulated as when float feed carburetors are used. While the primitive forms gave fairly good results with high grade gasoline, they do not carburet the lower grades of fuel used to-day properly, and do not supply enough gas of proper consistency for the present types of engines. The most efficient modern power plants utilize float feed carburetors instead of simple mixing valves. The advantage of the float construction is that the gasoline is maintained at a constant level regardless of engine speed. In the simple forms of generator valves in which the gasoline opening is controlled by a poppet valve, a leak in either valve or valve seat will allow the fuel to flow continuously whether the engine is drawing in a charge or not. During the idle strokes of the piston when there is no suction effect exerted to draw in gasoline vapor, the liquid fuel will collect around the air opening, and when the engine does draw in a charge it is excessively rich because it is saturated with globules of liquid fuel.

With a float feed construction, a constant level of gasoline or other fuel is maintained at the right height in the standpipe, and will only be drawn out of the jet by the suction effect of the entering air stream. The objection to the simple surface or wick feed is that the tendency is to draw off only the more volatile constituents of the fuel, and that after a time the heavier elements included in gasoline will remain in the vaporizer and will not be changed to gas. Obviously the engine

is not capable of utilizing all of the fuel. With a float controlled spray nozzle, the spray is composed of all the constituents of the liquid, and the lower grade portions that are mixed with those having higher evaporation points are drawn into the cylinder and burnt instead of settling to the bottom of the carburetor.

Elements of Carburetor Design.—The float-feed carburetor, with concentric float and mixing chambers, is the standard American type, and preference is given to automatic carburetors. In England, the practice is different, as the carburetors have separate float and mixing chambers for the most part, and are manually controlled instead of having automatic compensation for speed variation as is general in this country. In float-feed carburetors, the principle of mixing the gasoline vapor and air is the same as in the early forms of mixing devices, but the method of fuel supply is different. The device consists of two parts, a float chamber and a mixing chamber. The standpipe in the mixing chamber is connected to the float chamber, and the arrangement is such that the level of liquid in the float chamber is kept to a height equal to that of the spray nozzle. The fuel pipe from the tank or main container is coupled to the inlet pipe of the float chamber, and the opening is closed by means of a needle point carried by a hollow metal or cork float. The length of the needle is such that its point shuts off the gasoline supply when the level of gasoline in the float chamber coincides with the top of the standpipe. Whenever the fuel is drawn out of the float chamber sufficiently fast so the level is reduced, the float will sink with the decreasing liquid, and the passage in the fuel supply pipe is opened, allowing gasoline to flow into the float chamber until the liquid is at the proper height. Just as soon as the proper level is reached, the float and the needle it actuates are moved until the valve shuts off the flow of gasoline from the tank.

The concentric float chamber feature insures a constant level of fuel at the nozzle. When the nozzle is carried at one side of the float chamber, if the carburetor tilts, as is possible when climbing or descending a grade, if the float chamber is higher than the nozzle, the carburetor will flood. If conditions are reversed, the level of fuel in the spray nozzle will not be high enough, and the mixture will be too thin. With the spray nozzle placed at the central point of the device,

no reasonable amount of tilting will change the height of the liquid at that point, and a mixture of constant proportions is insured under all abnormal as well as normal operating conditions. The advantages of this construction do not seem to be properly appreciated by European designers, though generally accepted by American engineers.

Features of Automatic Carburetors.—The simple form of float feed spraying carburetor has disadvantages that made improvements in construction necessary before it became really efficient. One of these was that as the engine speed increased, the suction effect augmented in proportion, and as more gasoline was sprayed into the mixture because of the higher degree of vacuum created in the cylinder, the mixture became too rich at high speed. This is the main reason for the introduction of the modern automatic carburetor, such as shown at Fig. 128. In this device, the needle valve is mounted concentric with the float, i. e., the mixing chamber passes through the center of the carburetor, while the bowl, in which a horse-shoe shaped float is placed, surrounds the mixing chamber. The air pipe is constricted around the spray nozzle in order to get the proper air speed to insure positive suction of liquid at low engine speeds. At high engine speeds, when the mixture would be too rich in the simple form of carburetor, an automatic auxiliary air valve, which is carried to one side of the mixing chamber, opens and admits air to the mixture to dilute it. In the English carburetors, it is necessary to regulate the air supply with every change in engine speed, as it is believed that this is the only way to secure maximum economy. An automatic carburetor obviously must give average results, and intelligent hand regulation means that the best mixture for any engine speed can be selected by trial instead of approximated by an initial setting of the carburetor.

Typical Motorcycle Carburetors.—One of the most popular of all motorcycle carburetors, and the type which has undoubtedly received the widest application because it has been a standard fitting on the Indian motorcycle since its inception, is illustrated at Figs. 126 and 127. The external view at Fig. 126 will assist in making clear the action, while the arrangement of internal parts can be readily ascertained by consulting the sectional drawing at Fig. 127. This design originated through a desire of its inventor, Oscar Hed-

strom, who was then building motor-pacing tandems, to eliminate the continual shifting of an air valve every time the throttle was moved, as was true of the early carburetors and even present-day foreign designs. The Hedstrom was the first automatic carburetor to receive general approval, and was also one of the first to incorporate the concentric arrangement of float and mixing chambers that is so common at the present time. The automatic compensation feature was secured by a conical sleeve working in the mixing chamber, and actuated through a suitable connecting rod and crank arrangement attached to the throttle barrel. A manually regulated air shutter was provided to get a correct mixture when starting the machine, and when this has been set to provide a proper running mixture, the carburetor automatically took care of mixture variations and proper compensation was made between the air and the gasoline as the throttle was moved. In the latest form of Hedstrom carburetor, a pilot jet is provided in a separate mixing chamber which facilitates starting the motor and insures steady running at low engine speed. This carburetor was one of the contributing causes that made the Indian machine superior to the earlier forms of foreign and domestic manufacture, because it provided a much better and more uniform mixture than the mixing valves and surface vaporizers that were generally employed, and permitted greater engine speeds and flexibility.

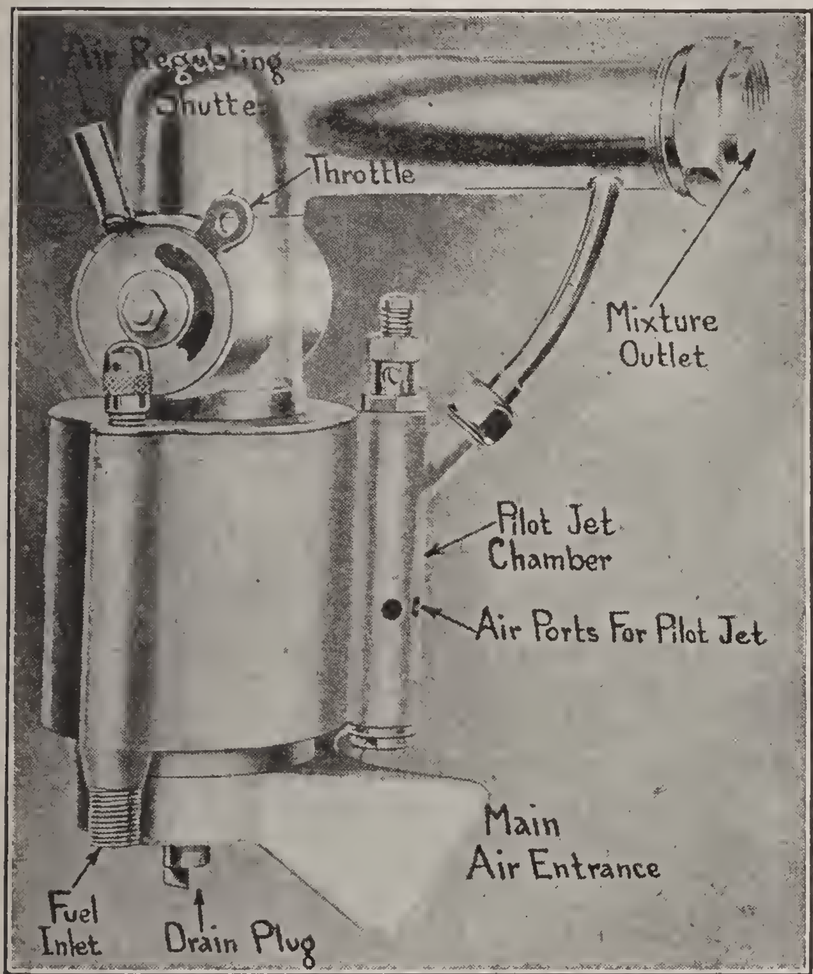


Fig. 126.—The Hedstrom Automatic Carburetor Used on Indian Motorcycles.

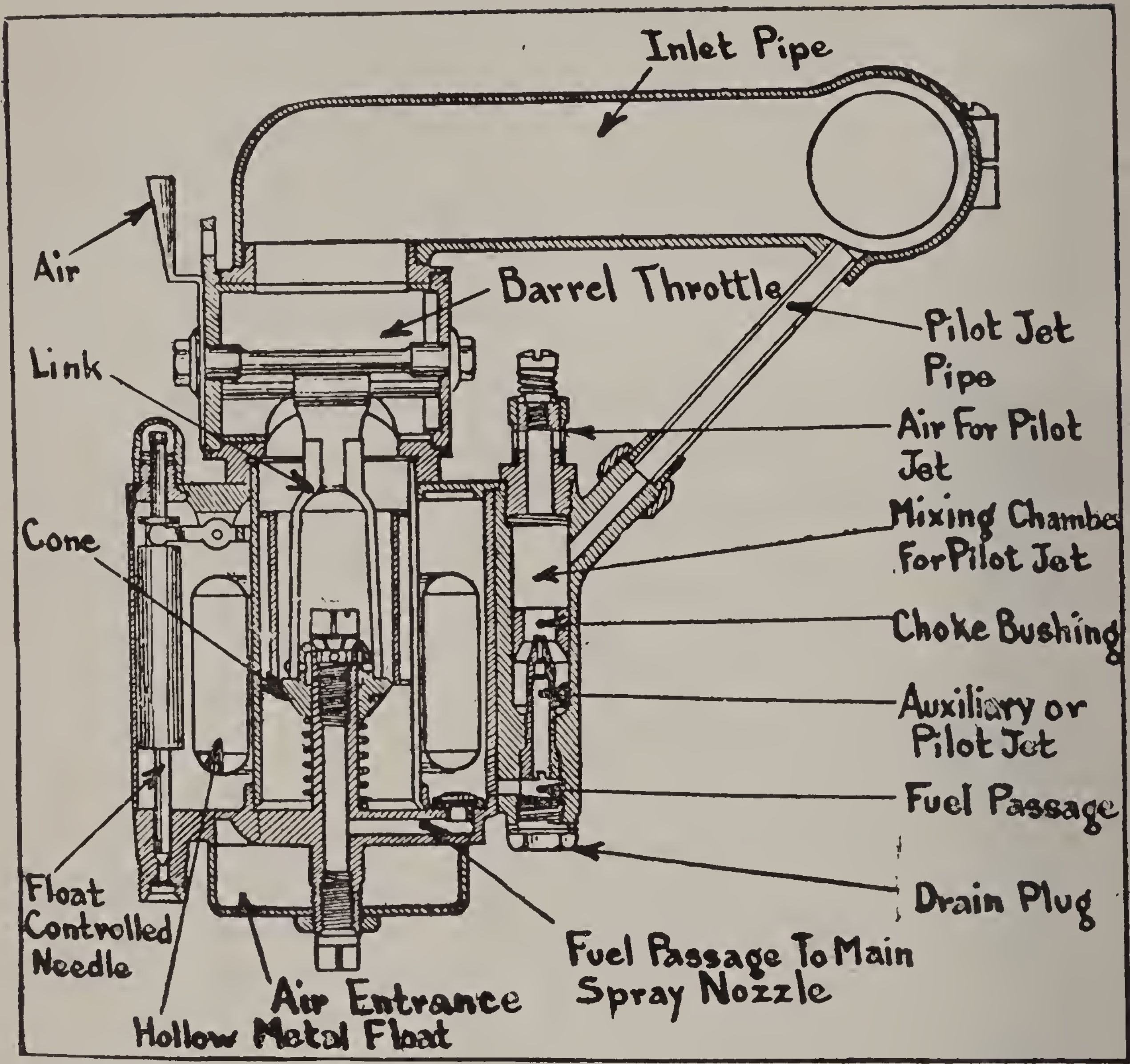


Fig. 127.—Sectional View Showing Interior Arrangement of Hedstrom Automatic Carburetor.

Sectional views showing the construction of the Schebler motorcycle carburetor are presented at Fig. 128. This is a concentric form, and a feature of merit is the method by which the fuel supply is augmented as the throttle is opened. The adjusting needle valve is carried on a bell crank which can be rocked by a cam forming part of the throttle linkage. This cam is so arranged that as the throttle is opened a spring, bearing against the bell crank member, will raise the needle from its seating in the spray nozzle and permit more gasoline to enter the mixture. The auxiliary air supply is regulated by altering the tension of the spring used to keep the air valve seated. In the Hedstrom carburetor, the float is of hollow metal, whereas in the Schebler a cork float is utilized. The method by which the float

shuts off the flow of fuel from the tank when it reaches the right height in the float chamber is practically the same in all carburetors. A lever of the first class transmits the upward motion of the float to the needle, which moves in the opposite direction, and which shuts off the fuel inlet when the liquid reaches the proper level in the float chamber.

In the Kingston carburetor, shown at Fig. 129, the concentric float and mixing chamber are retained, as this construction may be said to represent standard American practice. A feature of the device is the use of a series of balls of varying weight to control the auxiliary air ports. As the throttle is opened, and the suction becomes greater,

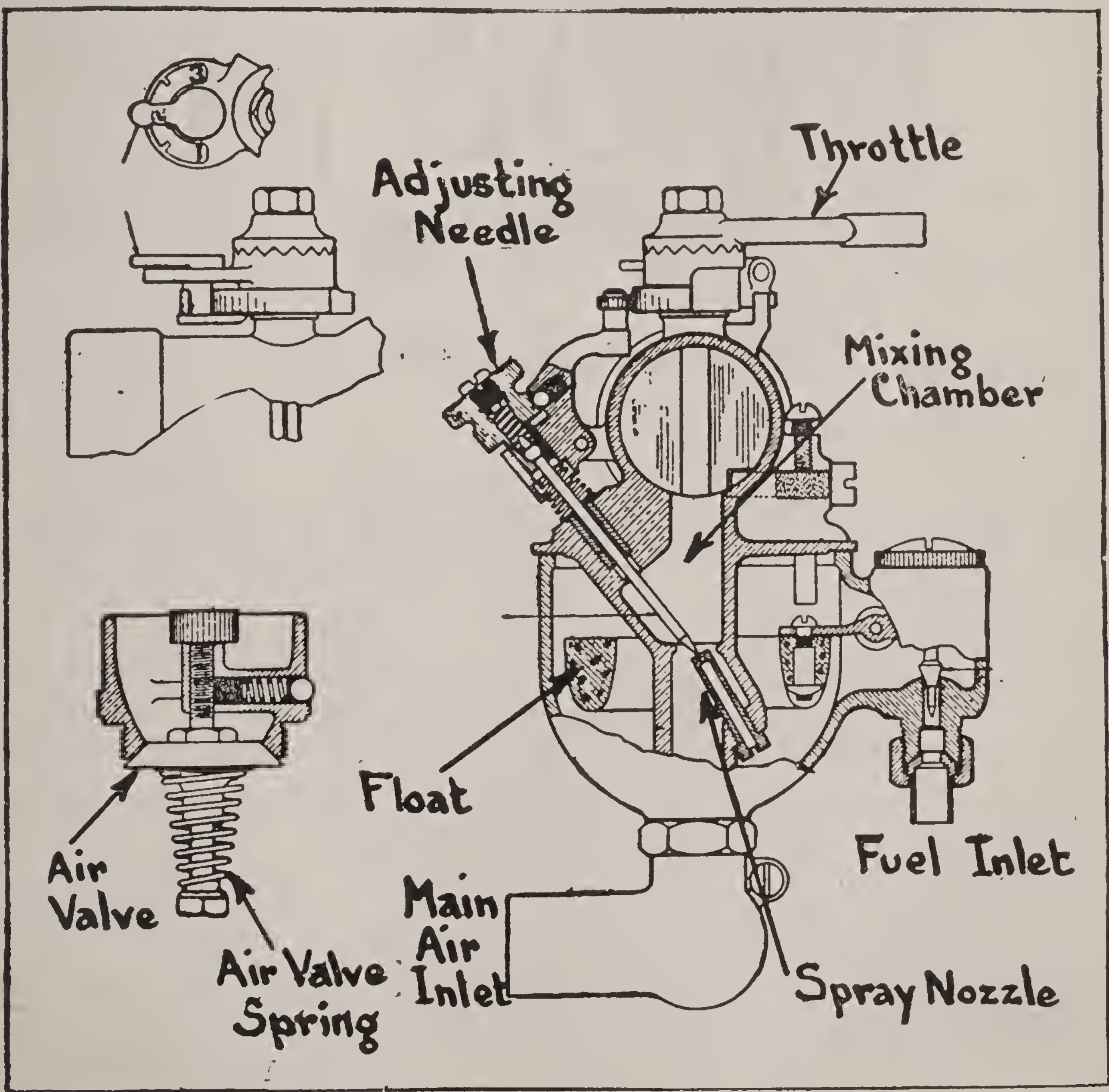


Fig. 128.—Schebler Motorcycle Carburetor.

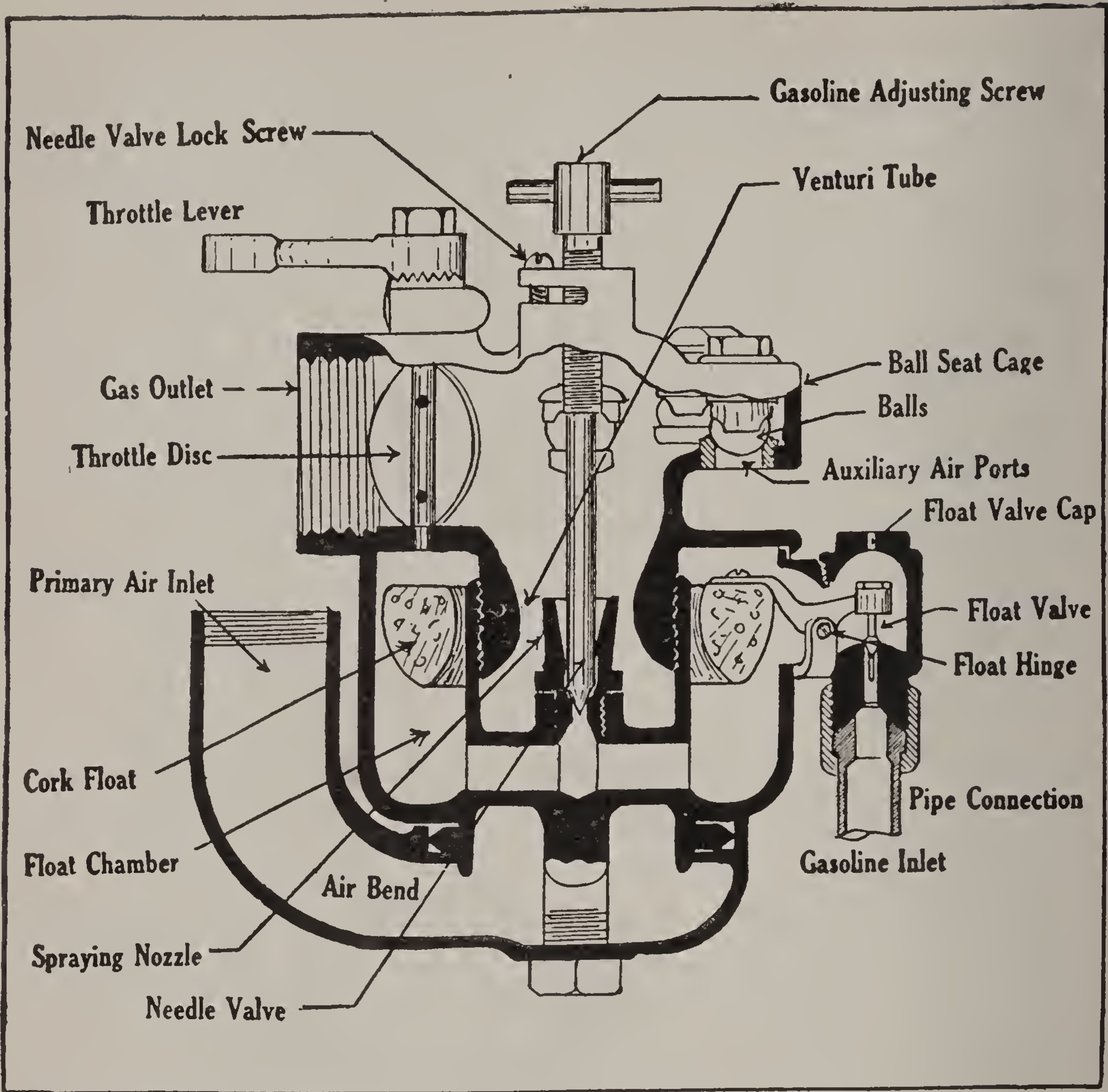


Fig. 129.—The Kingston Automatic Carburetor With Auxiliary Air Control by Ball Valves.

the balls open progressively and admit more air to the mixture. In this carburetor, no provision is made for altering the amount of auxiliary air under the control of the rider, but, instead, mixture proportions are altered by a needle valve which determines the amount of fuel sprayed from the stand pipe.

At Fig. 130, sectional views of the Breeze carburetor are depicted and in this form automatic regulation of the fuel supply is possible, as the throttle is opened because of a direct mechanical interconnection between the throttle lever and the regulating needle valve, as outlined at Fig. 131. The auxiliary air supply is regulated by means of a flat seated air valve provided with the usual adjustable reseating spring.

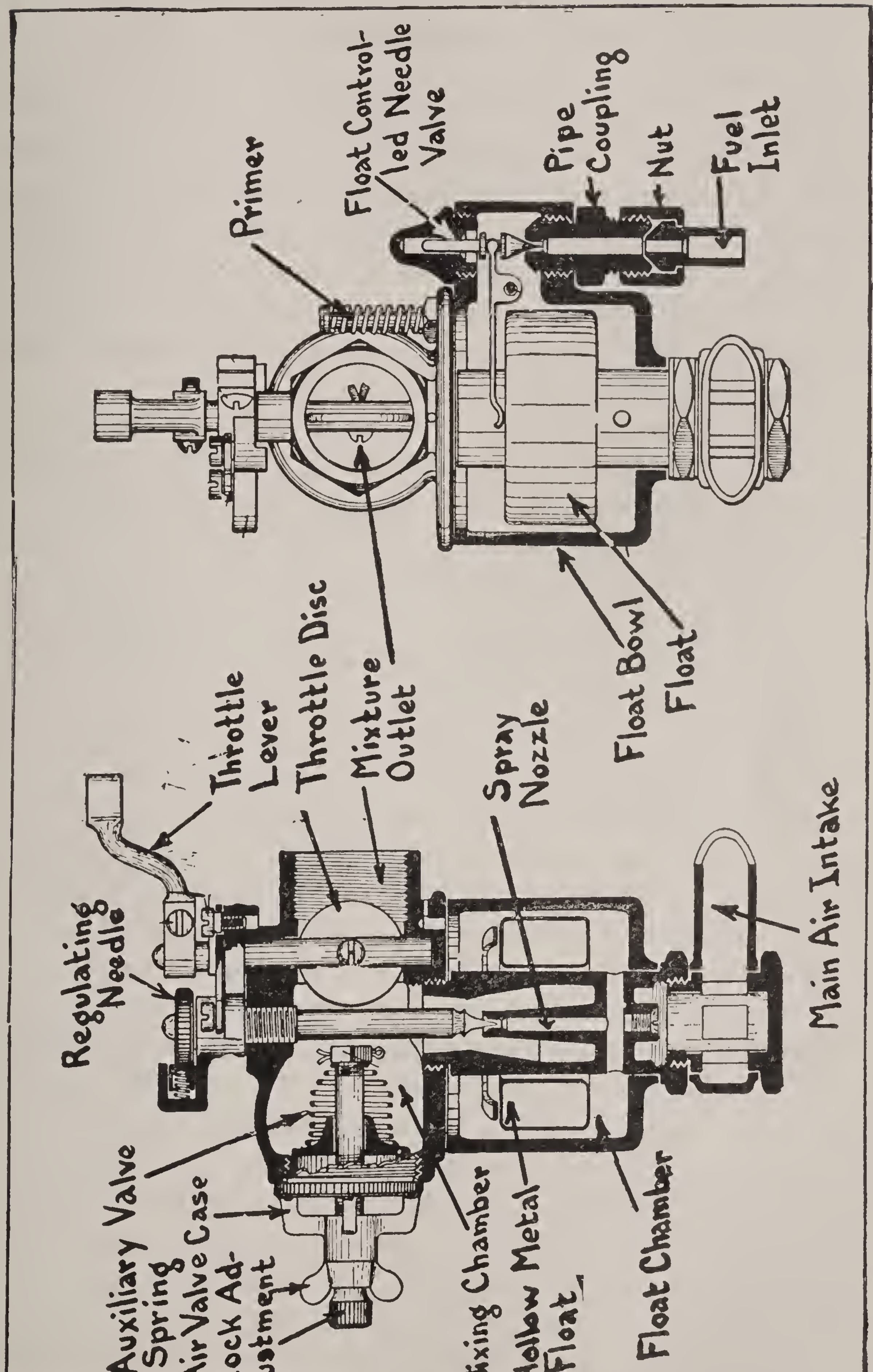


Fig. 130.—Sectional Views Showing Construction of Breeze Motorcycle Carburetor.

The manner in which the mechanical interlock between the needle valve and throttle lever works can be readily determined by observing the relative positions of the numbers on the regulating needle valve top with the throttle in the closed and opened position. It will be observed that in the closed position, the figure 1 is approximately in line with the center line of the carburetor, whereas when the throttle is opened the needle valve has opened sufficiently so the numeral 3 now registers with the carburetor center line. Practically all carburetors include a "tickler" or primer provided so the float can be depressed several times to cause gasoline to overflow the spray nozzle and thus provide a rich mixture for starting.

Foreign Carburetor Designs.—Carburetors of English and French design are considerably different from those of American manufacture because the automatic feature is seldom utilized, and also because the float chamber is usually distinct from and set at one side of the mixing chamber. European carburetors are not only more bulky than our American forms but would not meet with much favor in this country on account of the constant manipulation of the air valve necessary every time the throttle is moved.

The Longuemare, a popular French carburetor, is shown at Fig. 132, while two representative English types are outlined at Fig. 133. The feature of the Longuemare carburetor is the design of the spray pipe which includes an ingenious method of regulating the quantity of fuel spray by a conical plug provided with a number of passages so the fuel is atomized in a number of fine streams instead of one large stream as is the case when a spray nozzle having but a single central opening is used. The small streams are more quickly vaporized and are more easily absorbed by the entering air than the one large stream would be. The amount of gasoline is varied by changing the depth or number of the passages cut on the face of the tapered plug. If the mixture is too rich, one or more of the grooves may be filled in with solder, whereas if it is not sufficiently rich, the grooves provided may be made deeper and thus allow more liquid to flow into the mixture. The form shown is provided with a heating jacket and when used, in connection with an air-cooled motor, a portion of the exhaust gas is usually deflected through this chamber to furnish heat. It is not customary to provide these heating chambers on motorcycle carburetors.

The English carburetors shown at Fig. 133 are practically the same in principle, the only difference being in details of construction. For example, that on the left employs a counter-weighted float arrangement, while that at the right is considerably simpler because the float needle which regulates the main fuel inlet is attached directly to the float and moves in the same direction. The method of auxiliary air regulation, and also the throttle control in the device at the left, is by semi-circular slides which are normally pressed down by springs,

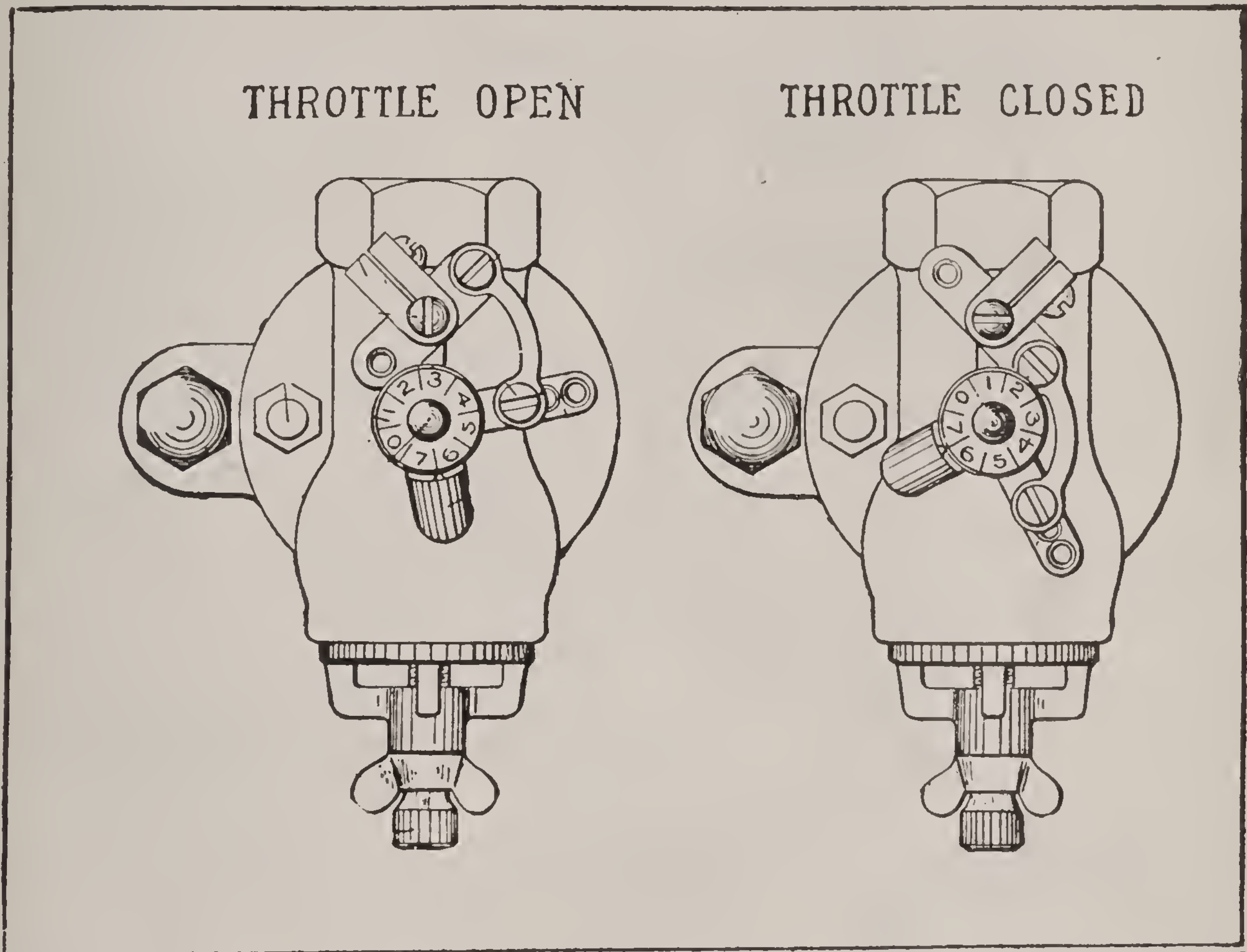


Fig. 131.—Top Views of Breeze Motorcycle Carburetor, Showing Mechanical Interlock Between Throttle and Mixture Regulating Needle.

so as to regulate the size of the extra air opening or that leading to the engine. These slides are adapted to be worked from the handle bars through Bowden wire control. In the device at the right, concentric slides are utilized to regulate the proportion of air admitted the mixture, and the quantity of gas supplied the motor. The outer slide is the member controlling the extra air, while the inner member regulates the supply of gas. In the American carburetors having a

needle valve pointing directly into the spray nozzle, an advantage of some moment is gained by breaking up the entering fuel stream into a spray. In the English device, at the right of Fig. 133, a small spraying cone is attached to the throttle slide that is intended to perform the same function.

It is desirable to interpose some form of strainer or filter in the gasoline line between the tank and the carburetor in order to prevent

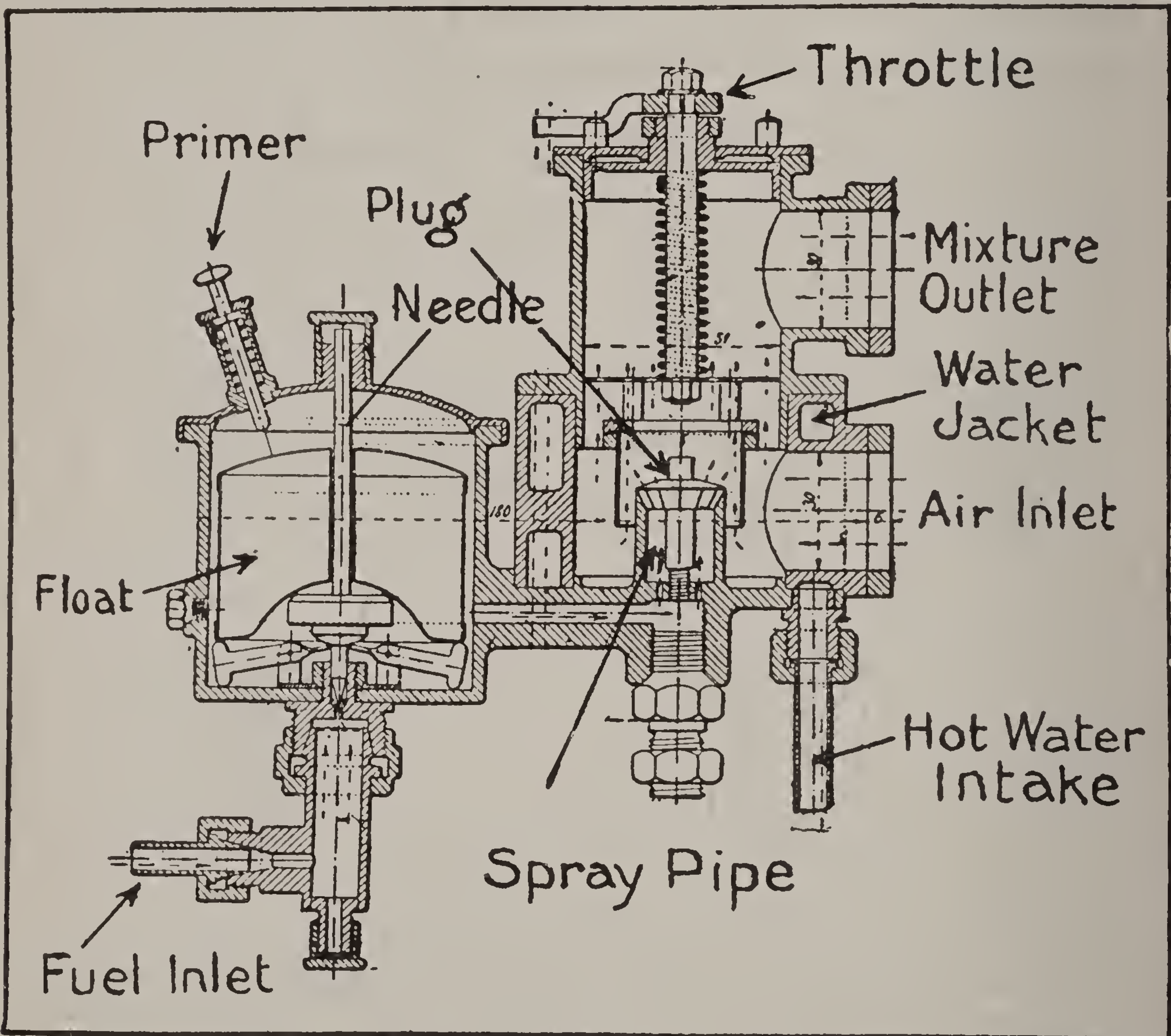


Fig. 132.—The Longuemare Carburetor, a Representative French Design.

dirt or water from reaching the interior of that device. Two typical straining devices are outlined at Fig. 134. In both of these, a gauze screen is used to separate the dirt from the gasoline, and a settling chamber is provided in which all dirt or water collects instead of flowing to the carburetor. Suitable drain cocks are provided so the settling chamber may be cleaned out when necessary.

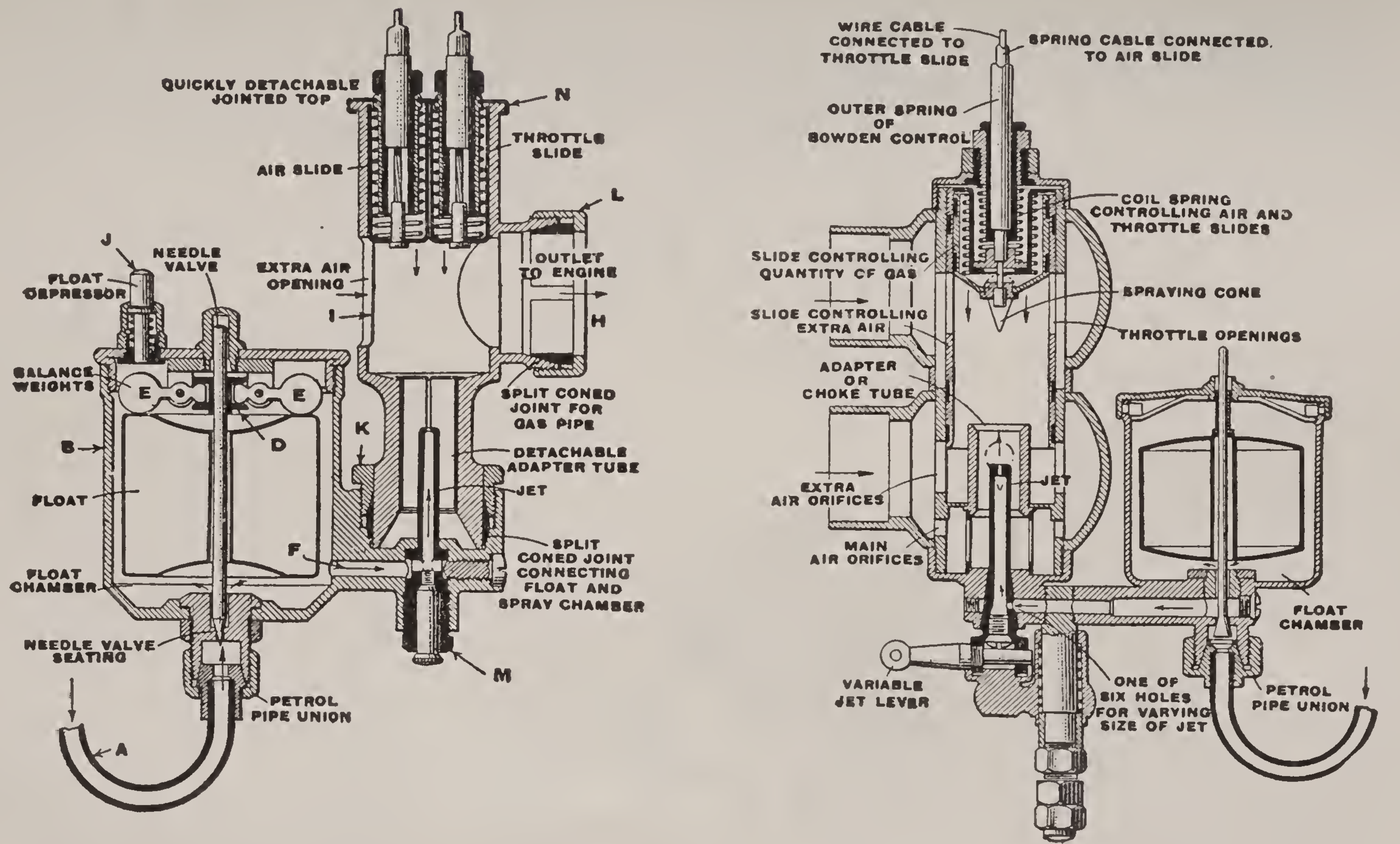


Fig. 133.—Sectional Views of Typical English Carburetors, Showing the Placing of the Float Chamber at One Side of the Mixing Chamber and the Air Regulation by Hand Operated Valves.

Another point that needs to be carefully observed to secure proper carburetion, in addition to the design of the vaporizer, is to proportion the intake manifold so the gas flow will not be obstructed and the charge will reach the cylinders promptly. The inlet manifold used on motorcycles is very simple when applied to twin-cylinder engines and in most cases endeavor is made to have the carburetor attached to the inlet pipe in such a way that it may be readily detached without disturbing the remainder of the piping, or the inlet pipe itself is fitted with suitable threaded connections at the ends so it can be removed from the valve chambers. Various forms of inlet pipes used in con-

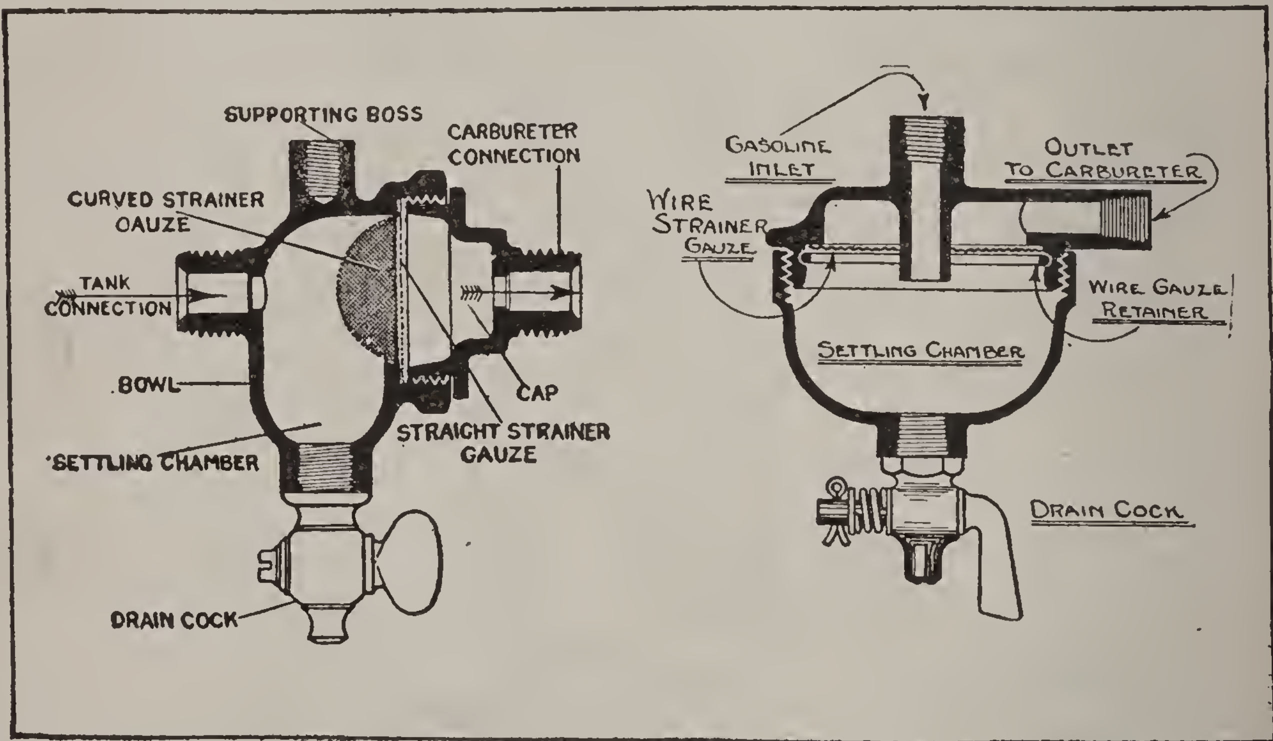


Fig. 134.—Strainers of Breeze Design to be Interposed Between Gasoline Tank and Carburetor for Preventing Passage of Water or Sediment to the Mixing Device.

nection with twin-cylinder engines are shown at Fig. 135. At A, the inlet valve dome castings have extensions to which a very short fitting carrying the carburetor is attached. At B, the manifold is a one-piece member attached to the inlet valve domes by easily removable retaining couplings. The construction at C is similar to that shown at B, except that it has a more pronounced curvature. In the manifold shown at A, the intake pipe is straight, whereas in those shown at B and C the gas passages are laid out with curves that are intended to provide an easy path from the carburetor to the cylinder

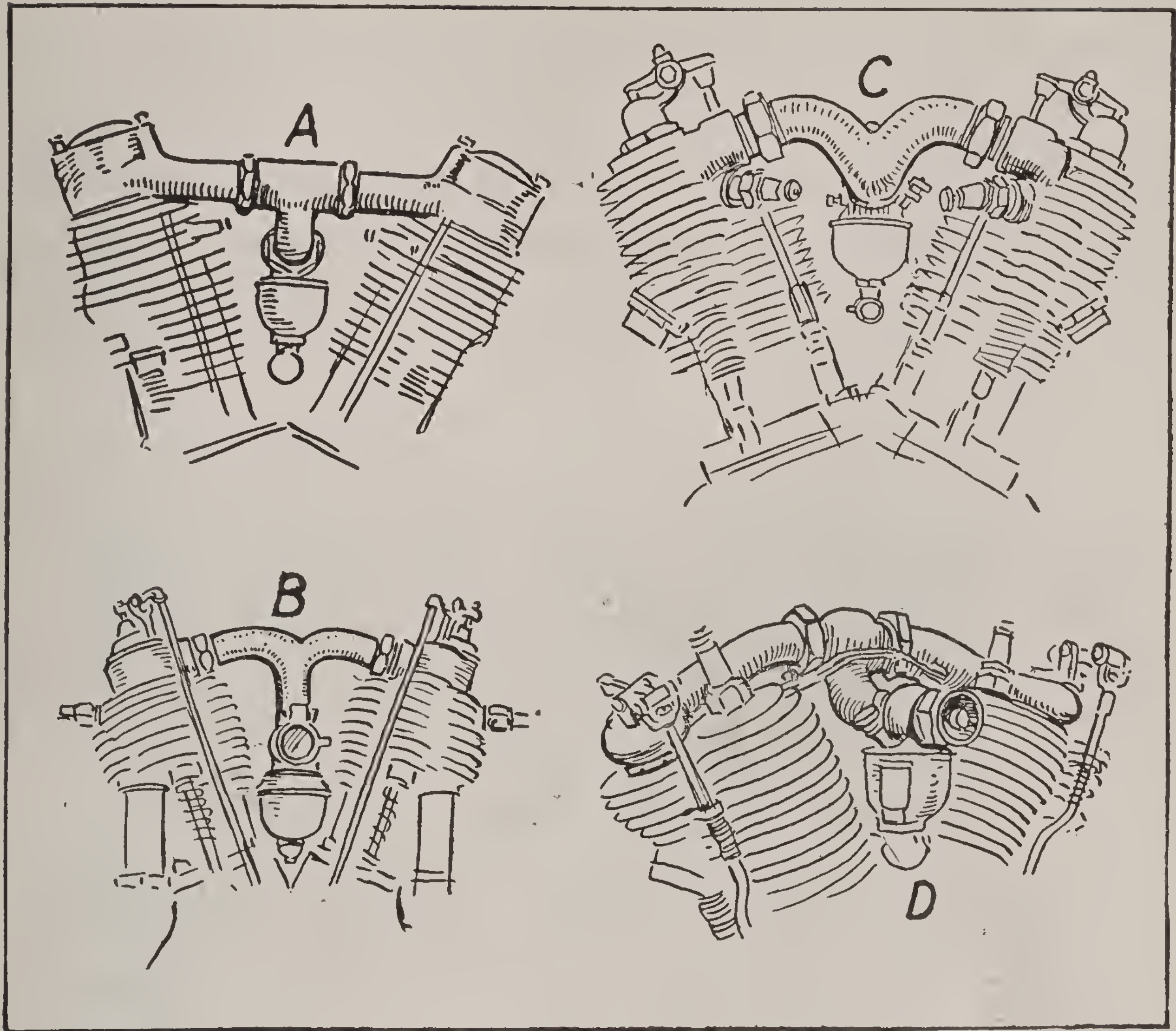


Fig. 135.—Design of Inlet Manifold for Twin Cylinder Motorcycle Power Plants. A—De Luxe. B—Emblem. C—Monarch. D—Fielbach.

interior. The form shown at D is also laid out in curves, but instead of the manifold rising from the carburetor to the valve chamber the pipes leading from the central fitting to which the carburetor is attached have a pronounced drop to the top of the cylinder.

The design of a suitable inlet manifold for a four-cylinder engine is one that calls for considerable judgment, as it is not practical to use the same type of a manifold as is employed on automobile motors owing to lack of space, and also because the carburetor must be carried at one end instead of at the side of the engine. It is possible to design an inlet manifold for a four-cylinder automobile motor that will give practically the same length of passage from the carburetor to any one of the four cylinders, and each cylinder receives the same quantity, and presumably the same quality of explosive mixture. As

an example of a four-cylinder manifold, that used on Pierce engines is shown at Fig. 136. Viewed from the exterior, it would appear that the intake pipe was a simple tubular member having a branch leading to each cylinder, but when one examines the sectional view it will be seen that a partition wall is placed in the interior, and that this compensates in a degree for the difference in distance between the inlet valve of the first cylinder and the carburetor carried at the rear of the motor.

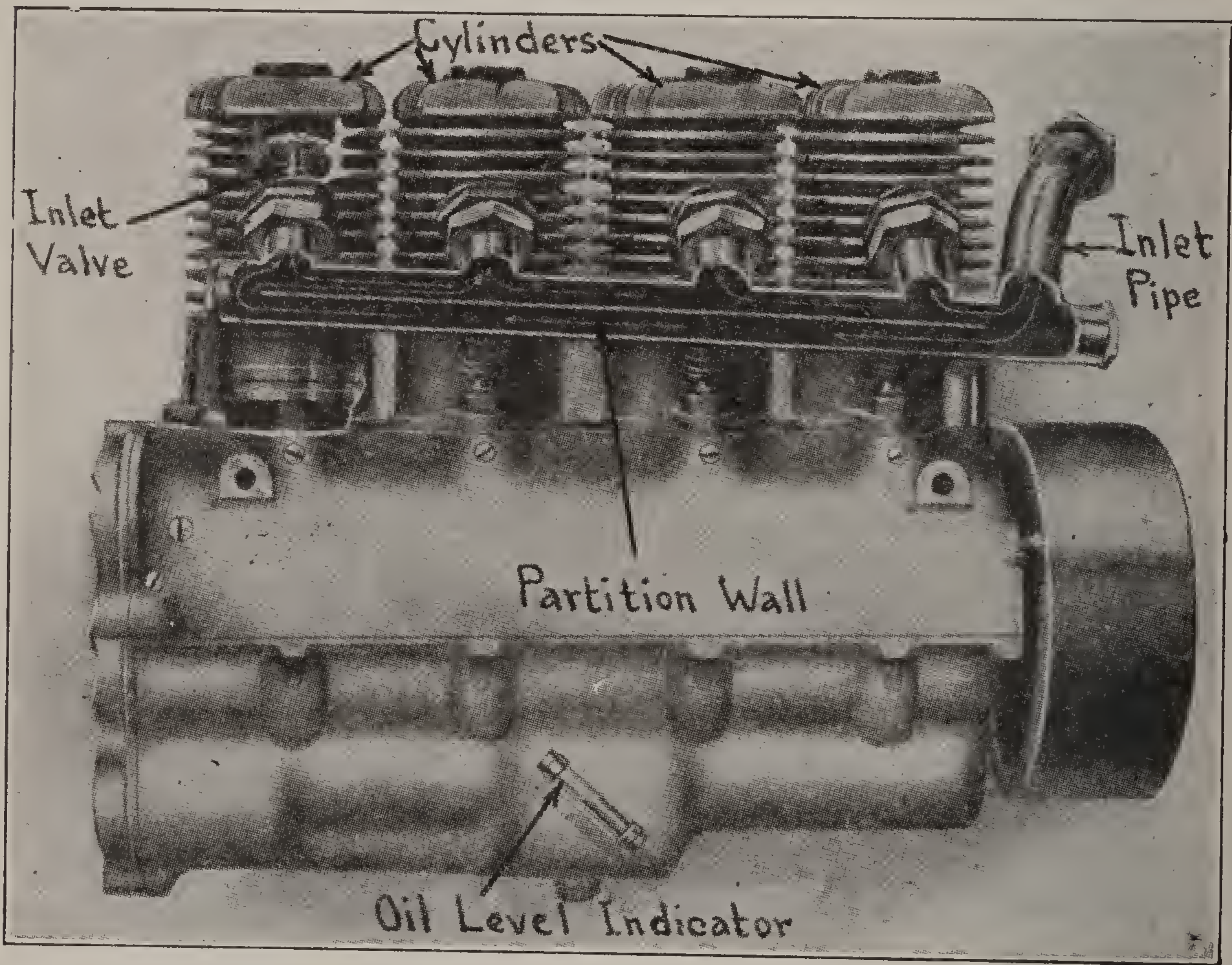


Fig. 136.—Inlet Manifold for Four Cylinder Motorcycle Power Plant.

Typical Mufflers and How They Operate.—After the charge of gas compressed in the cylinder has been ignited, and even when the piston reaches the bottom of its stroke, the exhaust gas still has considerably more pressure than the atmosphere. It is said that the pressure of the exhaust gases discharged through the exhaust valve when that member is first opened is about 40 to 45 pounds, and if the gas is discharged directly into the air, the vibration caused by the

violent ejection of the gases produces a noise comparable to a gunshot. The function of the muffler is to silence the exhaust by permitting the gas to expand to approximately atmospheric pressure before it reaches the air. One of the difficulties incidental to muffler design is to provide a form that will be effective as a silencer, and yet not offer appreciable resistance to the flow of the gases as this produces a back or negative pressure on the piston top when rising on the exhaust stroke which reduces the power output of the engine. This problem is not a difficult one for automobile designers to solve, because they have plenty of space available and can make the expansion chambers large enough so that there is ample space for the gas to expand before leaving the muffler interior. It is only necessary to provide an expansion chamber of a little more than three times the cubical capacity of one of the cylinders, and to break up the entering gas stream to facilitate its expansion, and one obtains a very effective muffler that offers no appreciable back pressure. In motorcycle practice, it is necessary that the muffler should be small and not occupy much space, so it is seldom that the motorcycle muffler will have more than the cubical capacity of the cylinder to which it is applied. When one considers that the gases are being discharged into a silencer at a velocity of 6,000 to 7,000 feet per minute, with the

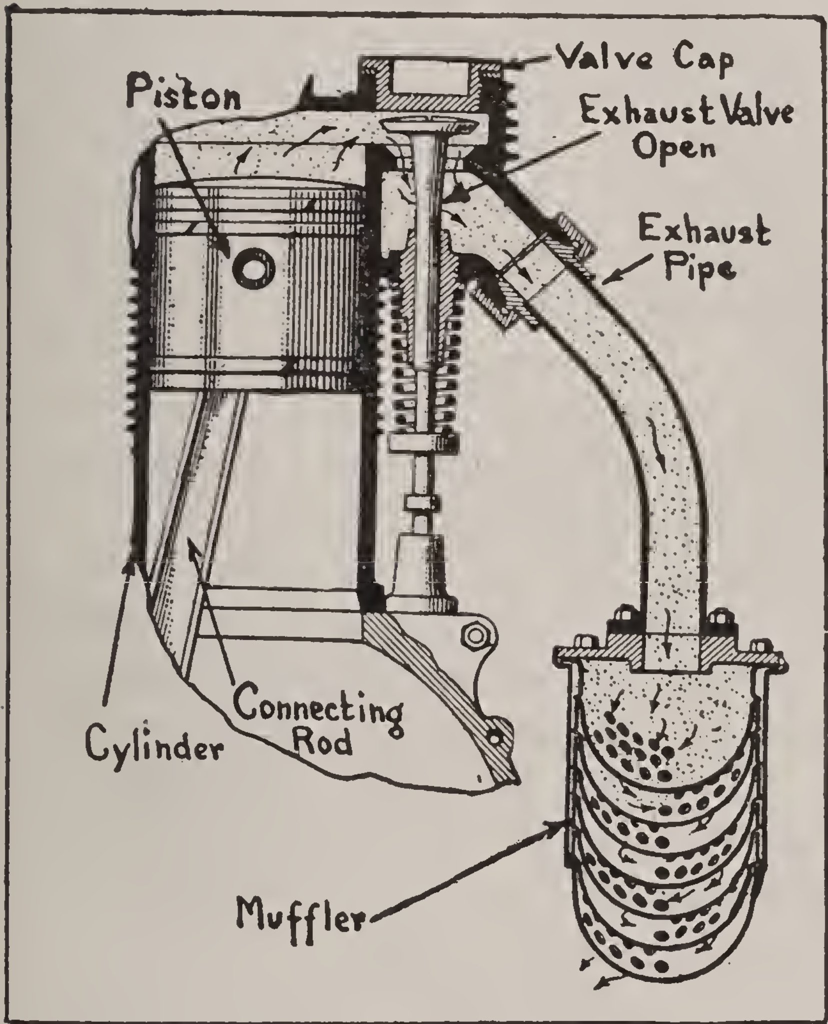


Fig. 137.—Showing the Use of Muffler to Receive and Silence the Exhaust Gases Before They are Discharged to the Atmosphere.

motor running 2,000 revolutions, it will be apparent that it is a problem of some magnitude to dissipate the current of gas rapidly enough to break up its acoustic powers without producing a negative pressure against the piston.

The construction of a typical motorcycle muffler of English design is shown at Fig. 137. The principle of silencing involved is to break up the gas into a large number of small streams by the medium of perforated baffle plates through which the gas must pass before it is discharged to the air. The general practice is to provide one muffler for both cylinders because but one is exhausting at a time. Some of the foreign motorcycle builders provide a separate muffler for each cylinder as indicated at Fig. 138. The somewhat novel and effective silencing arrangement used on Iver-Johnson motorcycles is shown at Fig. 139. This consists of what is practically an extension of the exhaust pipe, perforated with a large number of holes. It is said to be reasonably silent, and as there are no baffle plates interposed to hinder the flow of gas, it offers minimum back pressure.

An efficient muffler of American design is shown in the sectional view at the bottom of Fig. 139. In this, the gas enters a large chamber which is separated into six compartments by four baffle-plate members and an inner cylinder. Before the gas can pass out, as indicated by the arrows, it must first pass through the perforated baffle plates into an intermediate expansion chamber which communicates with a concentric cylindrical expansion chamber extending the length of the muffler. This has suitable perforations in its wall.

The endeavor of designers is to make mufflers that can be easily taken apart for cleaning which is a desirable feature in view of the oily character of the exhaust gas discharged from the average motorcycle power plant. In the form at Fig. 139, the various components are held together by a through bolt and the muffler can be easily disassembled by loosening one of the clamping nuts at the end of the bolt. The various parts may be removed from the main head fitting, and after all deposits of oil and carbon have been removed, it is a simple matter to replace the perforated cones around the central expansion chamber and clamp these members between the muffler heads by the retaining bolt. If cleaning is neglected, the openings in the baffle plates may become choked with carbon, and, as the area of

the passages is decreased, considerable back pressure will be present which may cause the engine to overheat.

Use and Abuse of the Cut=Out Valve.—Many mufflers are provided with a cut-out valve designed so that gas can be discharged directly from the exhaust pipes to the outer air instead of into the muffler interior. It is an advantage to include a cut-out with the muffler as this can be opened when full efficiency of the engine is desired as in speed work or hill climbing. The cut-out also affords an

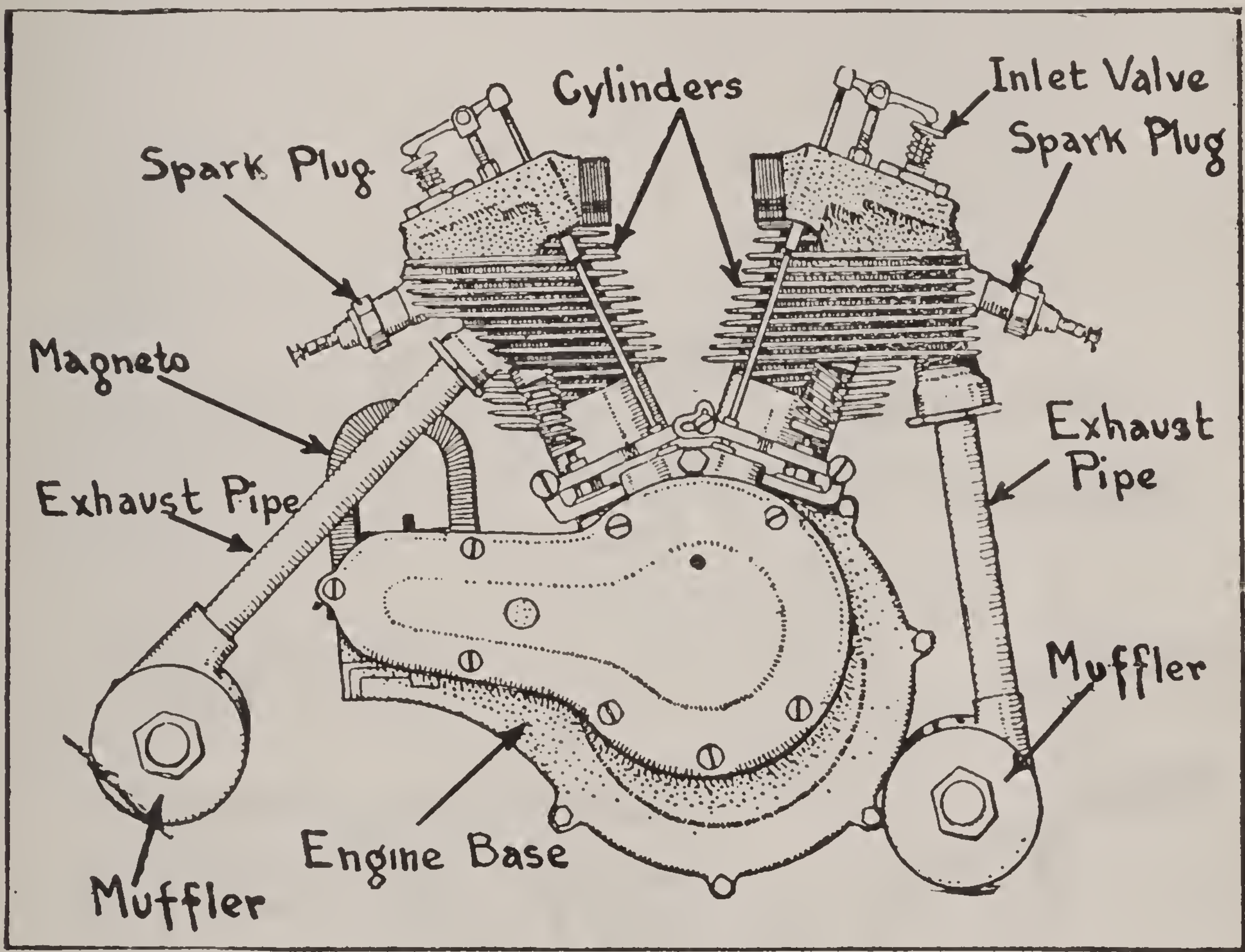


Fig. 138.—Premier Motorcycle Power Plant Which Utilizes Two Mufflers, One for Each Cylinder.

opportunity to judge the regularity of engine running, because the explosions can be heard easily with a cut-out opened. While the cut-out is a useful fitting, it has been abused in many instances by riders who leave it open in passing through towns or when using the motorcycle in traffic. In fact, the practice of running with an open muffler has been so general in the past that the impression conveyed to the layman has been that in silence of operation a motorcycle and a rapid

fire gun are synonymous. Practically all of the motorcycles on the market to-day are provided with effective and efficient silencers, and there is no excuse for running with a cut-out open in average touring work. Some manufacturers are successfully combating the open muffler evil by eliminating the cut-out fitting altogether which makes it imperative that all exhaust gases be discharged through the muffler. The arrangement of the cut-out and muffler of the Excelsior motorcycle is clearly outlined at Fig. 140. The muffler head has the branches, in

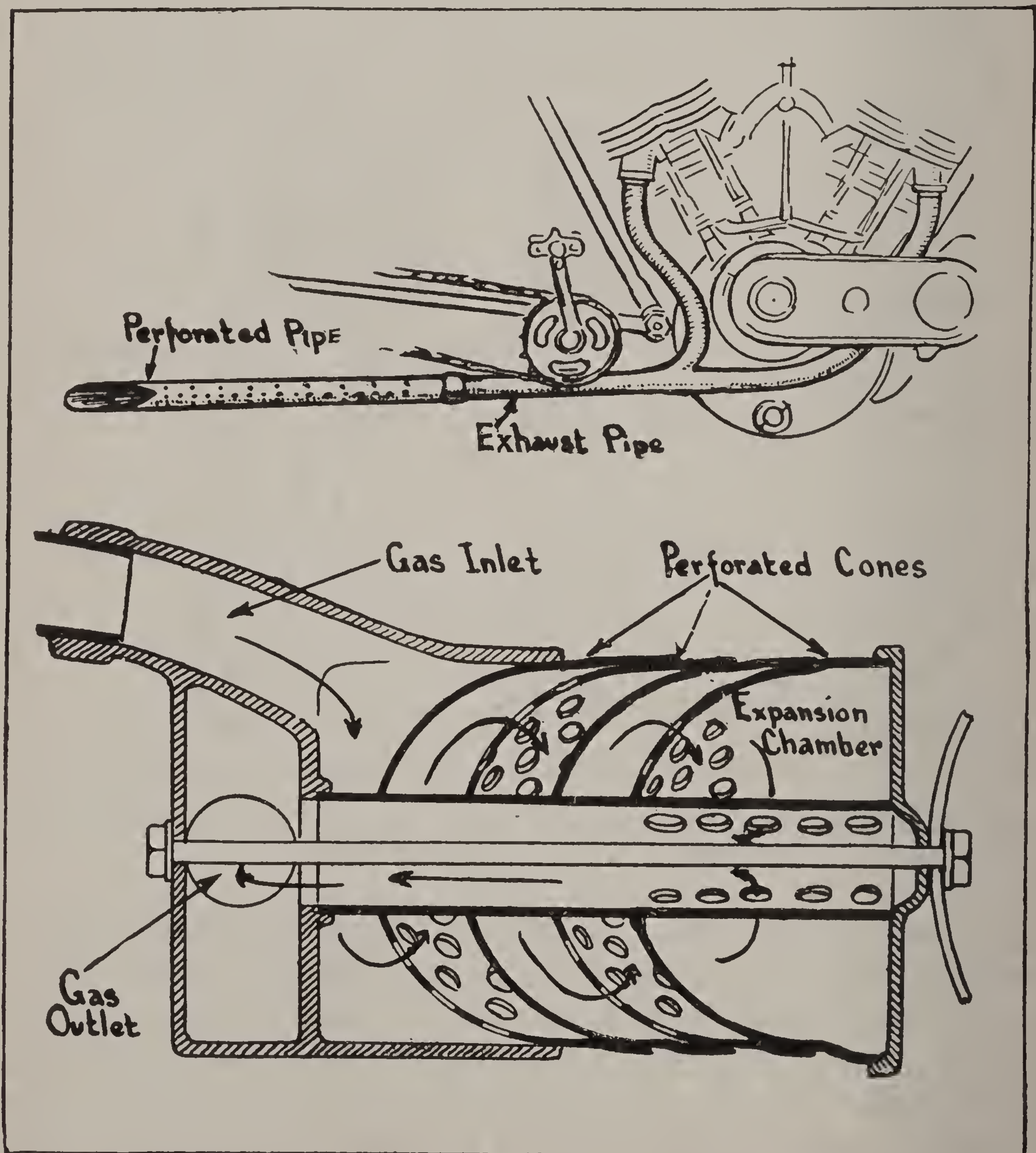


Fig. 139.—Typical Exhaust Silencing Devices.

which the exhaust pipes are secured, cast integral, and, at one side of the head, an opening is provided in this casting which is closed by a suitable damper or shutter easily worked by a small lever or crank to which it is attached. This crank can be moved easily with the foot, and can be opened or closed while riding as conditions dictate, and will stay in either the open or closed position.

How Compressed Gas is Ignited.—When the gas engine was first developed, the compressed gas was exploded by means of a naked flame which was permitted to communicate with the combustion

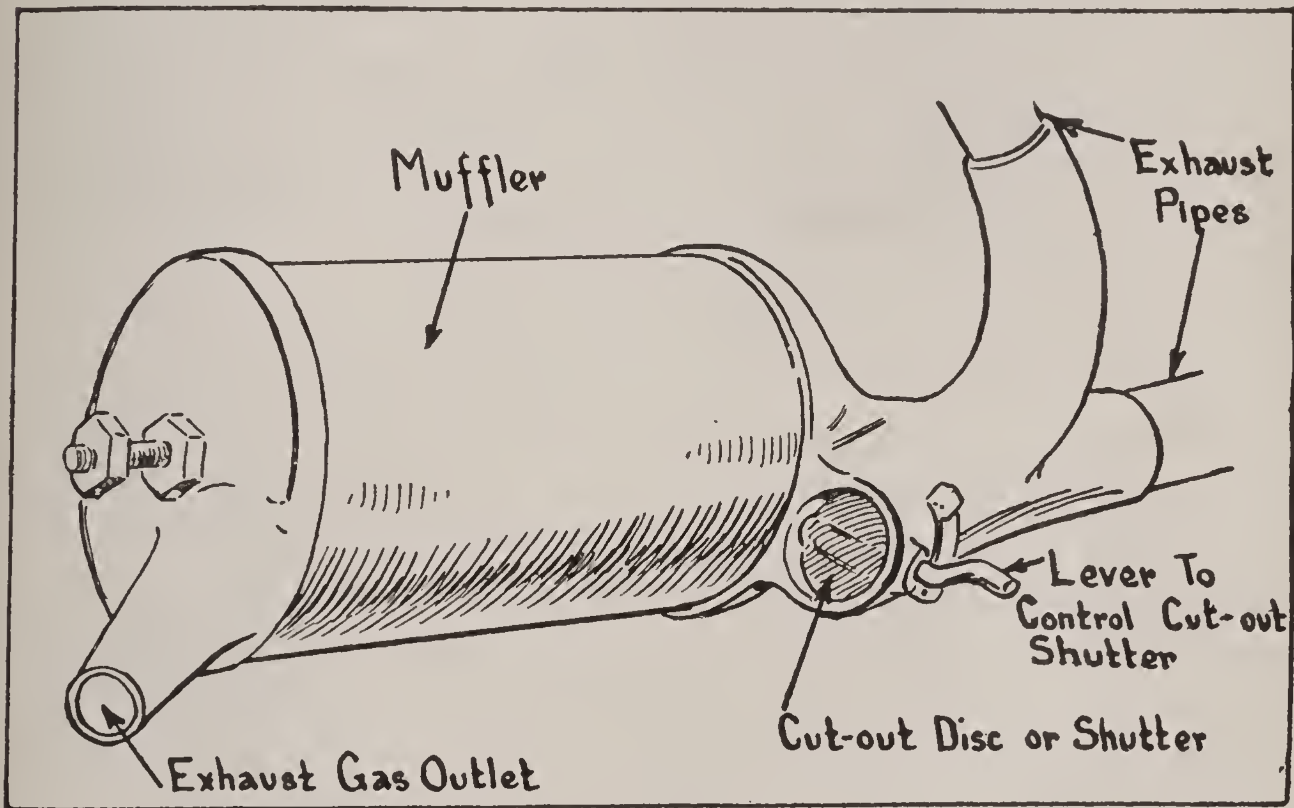


Fig. 140.—Method of Utilizing Exhaust Cutout Valve in Connection With Excelsior Muffler.

chamber interior by means of a slide valve which moved at the proper time to permit the flame to ignite the gas back of the piston. This system of ignition was practical only on the primitive gas engines where the charge was not compressed to any degree. When it became desirable to compress the gas before firing it, the hot tube system of ignition was used. This method involved the use of an incandescent platinum, porcelain or nickel tube in the combustion chamber, the tube or ignitor being kept in a heated condition by a flame burning in it. Another method depends upon the property of gases firing

themselves if compressed to a sufficient degree, provided that a certain amount of heat was stored in the cylinder head to insure complete vaporization of the gas, and help produce the proper kindling temperature.

Practically all of the gas engines in use at the present time, except those employed for stationary power that operate on the Diesel system, utilize electrical ignition systems. In all motorcycle and automobile power plants, the compressed gas is exploded by a minute electric arc or spark in the cylinder, the current for which is produced by some form of chemical or mechanical generator of electricity. The early forms of ignition systems had a disadvantage in that they were not flexible and could be used successfully only on constant speed engines. None of these methods are practical in connection with motorcycle power plants because they do not permit the flexible engine action that is so desirable and necessary.

While electrical ignition systems are somewhat more complicated than the other simpler types, they are the most efficient, and as their peculiarities are now generally understood, there is no difficulty in applying them successfully. Two forms of electric ignition systems have been used, the most popular being that in which a current of electricity under high potential or pressure is forced to leap an air space between the points of a spark plug which is screwed into the cylinder. The other system, which is used to a limited extent on marine engines, is known as the low tension system because a current of comparatively low voltage is utilized instead of the high pressure current used in the more popular systems. Whereas the spark is produced in the high tension system by the current heating up the air particles between the points of the spark plug, it is produced in the combustion chamber when the low tension method is employed by moving electrodes which come in contact with each other, and which produce a spark as they separate.

The essential elements of any electrical ignition system are: First, a simple and practical method of current production; second, suitable timing apparatus to cause the spark to occur at the right point in the cycle of engine action; third, some form of igniter to produce the spark in the combustion chamber; fourth, apparatus to transform the low tension current obtained from batteries or dynamo to one of greater

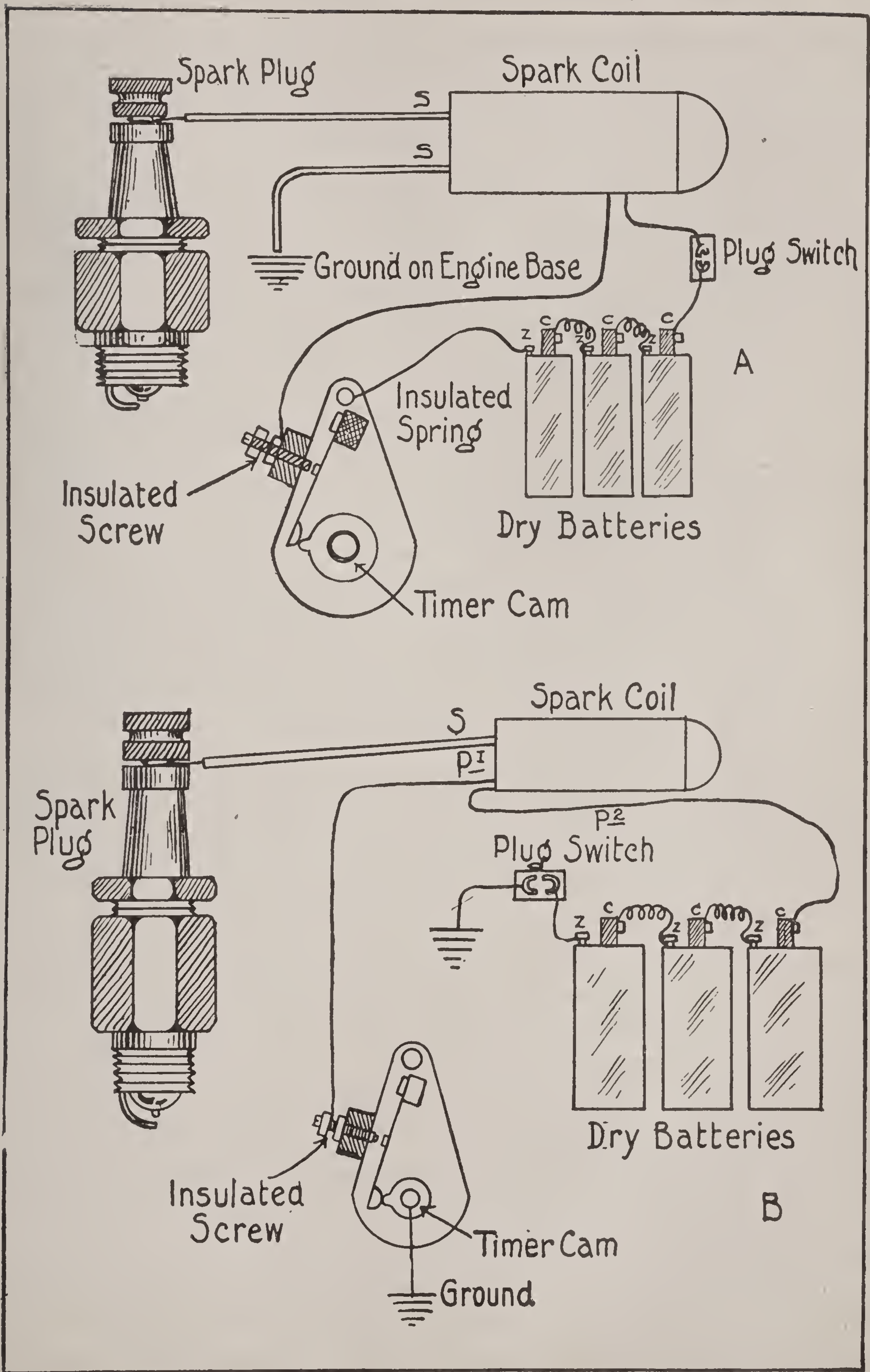


Fig. 141.—Diagram Showing Battery Ignition Systems for Single Cylinder Engines.

value before it can produce a spark in the cylinder; and fifth, suitable wiring, switches and other apparatus to convey the current produced by the generator to the auxiliary apparatus, and from these to the spark-producing member in the cylinder head.

There are two common means for obtaining the electrical current used to produce the spark in the cylinder, one of these depending on a chemical action, the other an electro-magnetic action. The first class includes the various forms of primary and secondary batteries, while the second group includes the various mechanical appliances, such as dynamos and magnetos. The simplest method of current generation is by means of a simple chemical cell, generally known as the "dry battery." These belong to the primary cell class because a current of electricity is generated by the oxidation of one of the elements of which the cell is composed by the electrolyte. Any primary battery consists of three main elements: First, a plate of some material which will be acted on by the electrolyte; second, an electrolyte which may be a solution of a salt or acid in water, which will have a chemical affinity for the active element; third, a neutral plate which serves to collect the electricity produced by the chemical combination of the electrolyte and active elements.

The dry battery is so called because the electrolyte is in the form of a paste instead of a liquid. The dry cell consists of a zinc can filled with electrolyte and a depolarizing chemical in the center of which a carbon rod or plate is placed. The function of the depolarizer is to keep the cells active for a longer period than would be the case if only a simple electrolyte was used. The zinc can serves as a container for the electrolyte and also forms the active member. The carbon rod is the neutral or collecting member. A terminal is attached to the zinc can and is known as the negative, commonly indicated by a minus sign thus (—) while the terminal attached to the carbon is known as the positive connection (commonly indicated by a plus sign +). It is to these terminals that the wires forming the external circuit of the cell are attached, the internal circuit being completed by the electrolyte and depolarizer.

A single dry cell does not have enough power to produce a spark, so a number of these are generally joined to form a battery. The common method of connecting dry cells is in series; this means that

the positive terminal of one cell is always coupled to the negative terminal of its neighbor. When cells are coupled in this manner, the battery has a voltage equal to that of one cell times the number of cells so joined. For instance, three dry cells would have a potential or current pressure of four and one-half volts, as one dry cell has a pressure of one and one-half volts. The amount of current produced by the batteries is measured in amperes and the battery capacity will depend upon the size of the active element and the strength of the electrolyte. The ordinary No. 6 dry cell which is six inches high by two and one-half inches in diameter will indicate a current strength of about twenty amperes. When cells are joined in series, the amperage of the set is equal to that of but one cell.

When dry batteries are used for motorcycle ignition purposes, they are always coupled together in a series connection to obtain the proper voltage and current strength. The dry battery has a number of advantages, chief among which are its cheapness, ease of installation, compactness and simplicity. It has the disadvantage of being limited in capacity and not suited for continuous work, which it shares with all other forms of primary battery. When dry cells are exhausted, there is no method of renewing them to efficiency, and they must be replaced. They are seldom used on modern machines.

The coming of electrical self-starting and lighting systems on motorcycles has created some degree of interest in storage batteries, and in one machine, the Indian, which can be obtained with full electrical equipment, the battery current is employed for ignition purposes as well as for lighting and for starting the motor.

The storage battery is a chemical current producer that is capable of being recharged when it is exhausted by passing a current of electricity through it in a reverse direction to that of the current given out. Storage batteries are composed of elements of practically the same material, and can only become active when a current of electricity is passed through them. The materials generally used are grids of lead filled with a paste composed of lead oxides. When the current of electricity passes through these plates, they become enough different in nature so that a difference of electrical condition exists between them, and when the cell is fully charged, a current may be drawn from it in just the same way as from a primary battery.

Storage batteries have the advantage that they may be used for continuous current production, and as they may be recharged when exhausted, it is not necessary to replace them with new members when they will no longer produce current. The storage battery is called a "secondary cell" because it can only give out energy after a current of electricity has passed through it, whereas a primary battery in good condition will produce electricity as soon as it is completed. The storage battery uses an electrolyte composed of dilute sulphuric acid and water, while a dry battery uses an alkaline electrolyte composed largely of sal-ammoniac.

The average form of storage battery used for ignition, lighting or starting purposes is really composed of a number of separate cells, which are placed in a common carrying case of wood or hard rubber. The connection between the cells is made by plates of lead which are burned to the elements, leaving but two terminals free, one of which is a negative member while the other leads from the positive plates. To prevent spilling of the electrolyte, the top of the cell or battery is sealed with a hard rubber plate over which is poured a pitch and rosin compound. The electrolyte is renewed through a small vent in each cell which is covered by a removable hard rubber cap. These vents also allow for the escape of the gases evolved when the cell is being charged or when it is delivering a current of electricity.

Parts of Simple Battery Systems.—The first system of ignition to be applied after the hot tube method had been abandoned was the various electrical systems in which batteries furnished the current. The wiring of two ignition systems for single-cylinder motorcycle engines is shown at Fig. 141, while a diagram showing the arrangement of parts and the method of joining them in a two-cylinder ignition system is outlined at Fig. 142. In the simple system depicted at A, Fig. 141, three dry cells are joined together in series to form a battery capable of delivering about 4.5 volts. This voltage would not be sufficient to leap the air gap or space between the points of the spark plug because it requires a pressure of several thousand volts to produce a spark between the plug points. Therefore, an important element of all battery systems is the transformer or induction coil employed to raise the voltage of the current so it will overcome the resistance offered by the air gap. It is not necessary to go deeply

into the theory of induction coil action at this time because none of the present day motorcycles, with the exception of the Hendee Special Model Indian, utilize these members or batteries for ignition. In its simplest form, the induction coil consists of a core composed of soft iron wire around which is wound two or three layers of No. 16 or 18 magnet wire. This is thoroughly insulated from another coil of very fine, thread-like wire comprising several thousand turns which is wound around the coil of coarse wire. The coarse wire is termed "the primary winding," because the energizing current from the battery flows through it. The fine wire, which is not in electrical connection with the battery, but which is excited by induction, is termed "a secondary coil" for this reason. In addition to the windings and core, a condenser is also included in the assembly which is contained in torpedo-shaped casings of hard rubber. Each time a current of electricity passes through the primary coil, an induced current of considerably higher voltage flows through the secondary coil. In order to insure that this rush of secondary current will only take place at such times that a spark is needed in the cylinder, a mechanically-operated switch termed the "timer," which is driven by the crankshaft of the engine, is interposed in the circuit between the batteries and the primary coil.

Considering first the four terminal coil shown at A, we find that two of the leads are insulated more heavily than the other two. The two wires with the thick insulation are secondary wires, and one is grounded while the other goes to the insulated terminal of the spark plug. The flow of secondary current is completed because the plug body, which carries one of the electrodes, is also grounded by being screwed into the cylinder casting. When a four-terminal coil is used, both terminals of the timer are insulated from each other, and the circuit is completed only when the platinum points on the timer spring and insulated contact screw are in contact. One of the primary wires, therefore, is attached directly to the insulated screw of the timer, while from the insulated contact spring another wire makes connection with the zinc terminal of the battery. The other primary terminal is connected to one side of a plug switch, while the wire from the carbon terminal of the battery is connected to the other. Before starting the engine, it is necessary to bridge the gap between the plug

switch members by a suitable metallic connector, and then, as the engine is rotated, the timer cam will bring the platinum points on the insulated spring and screw together, and close the primary circuit when the piston reaches the end of its compression stroke, and when the gas is fully compacted preparatory to explosion. Vibrator coils, which are very popular in automobile and marine service, are seldom used in motorcycle ignition systems, because with the high speed of the engine a single quick contact not only produces the required spark but means a considerable reduction in battery consumption. It is necessary to regulate the contact screw of the timer very carefully to secure the best results from the engine, and a difference of an eighth of a turn is often all that is needed to increase or reduce the engine speed appreciably.

The wiring diagram presented at B is practically the same as that outlined above it, except that one of the secondary terminals is joined inside of the coil to one of the primary leads which goes to the battery. The primary wire P-1 goes to the insulated screw on the timer, and the primary wire P-2 goes to the carbon terminal of the dry cell battery. The zinc terminal of the battery is attached to one of the segments of the plug switch while the other member is grounded. The timer cam, which is attached to a metal shaft, is also grounded, and the current flow from the plug switch to the timer cam is through the metal parts of the engine and frame. But one secondary wire, S, projects from the coil, and this, of course, goes directly to the insulated terminal of the spark plug.

When a two-cylinder engine is to be served by a battery ignition system, it is necessary to use two coils, one for each cylinder, and a two-point timer. The two induction coils are invariably housed in a single casing and are connected together inside in such a way that but five leads or wires extend from the coil case. Two of these are secondary wires, one from coil A and the other from coil B. The remaining two secondary leads are joined together inside of the coil casing and connected to the primary wire common to both coils. Two primary wires extend from the coil case that are electrically insulated from each other, as each of these serves an individual coil. The primary wire from coil A goes to the insulated contact at one side of the timer, while the primary wire from coil B is attached to the in-

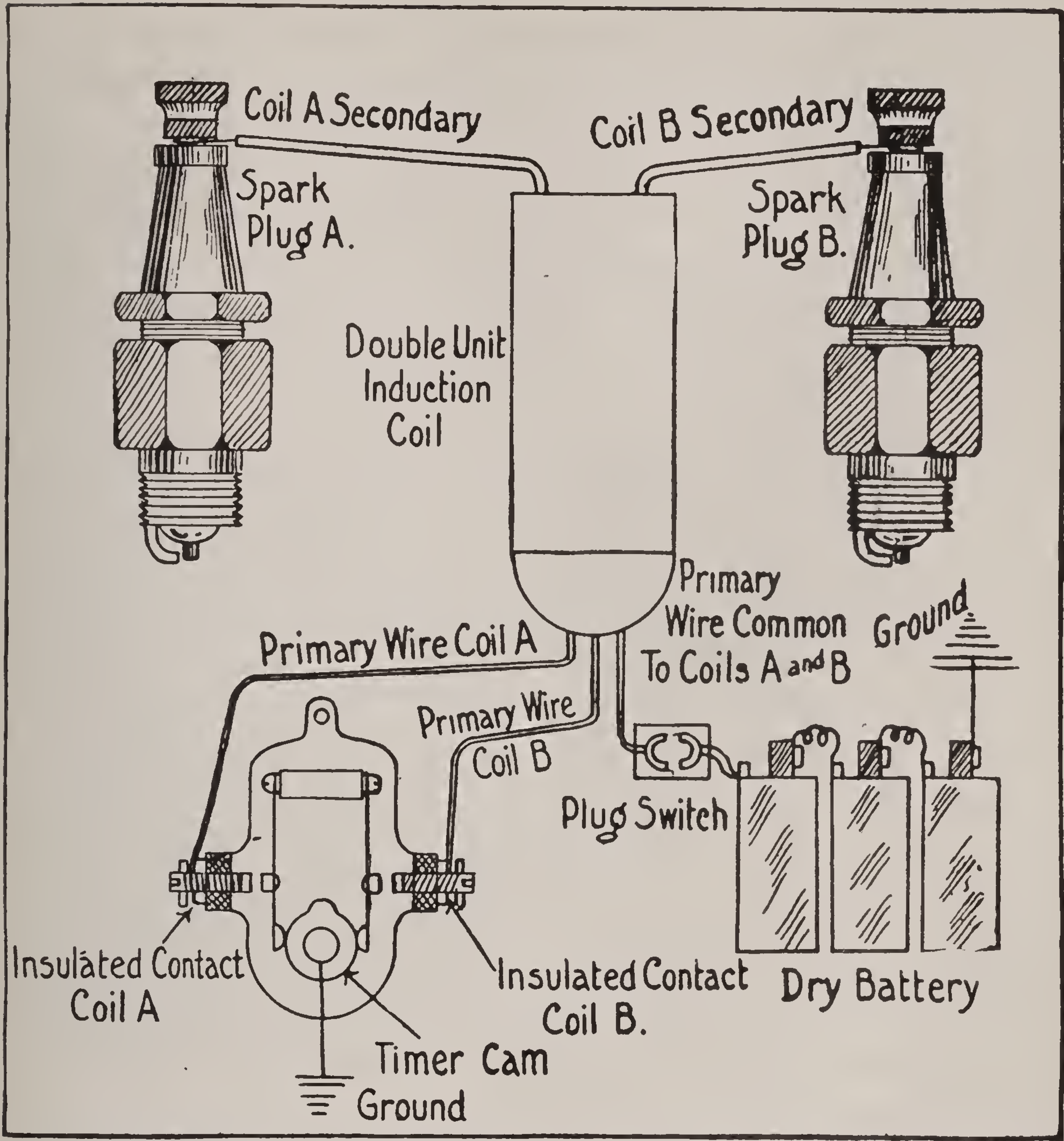


Fig. 142.—Diagram of Battery Ignition System for Two Cylinder Engine.

sulated contact at the other side. One end of the battery circuit is grounded as is also the timer cam. As the cam revolves, connection is made first between one pair of insulated contacts and then between the other. The spacing of the springs that are actuated by the cam is such that the explosions occur at the proper time in the cylinders and depend upon the method of placing the cylinders and design of the crankshaft. In the timer shown at Fig. 142, the explosions are separated by even intervals because the cam contact blocks on the timer springs are opposite each other and separated by a space equal to 180 degrees or half a revolution of the timer-cam travel.

A timer used for single-cylinder engines is shown at Fig. 143 with all parts clearly indicated and one for two-cylinder power plants at Fig. 144. The basis of the timer is often a block of fiber to which suitable binding posts are attached to support the vibrating spring and the contact screw. In the form outlined, these members are attached to terminals secured to the timer base by means of internal wires or suitable metallic connections. The wires comprising the outer circuit are attached to these terminals. The cam of the timer, shown at Fig. 143, is different in form from that at Fig. 144. The former normally keeps the spring out of contact with the platinum-pointed contact screw, and an electrical connection is established only when the cam rider or block on the end of the vibrator spring falls into the notch cut into the periphery of the cam. In the form at Fig. 144, the cam has a raised portion which lifts the springs into engagement, and establishes a connection by positive mechanical means instead of depending upon the spring tension as in the other construction.

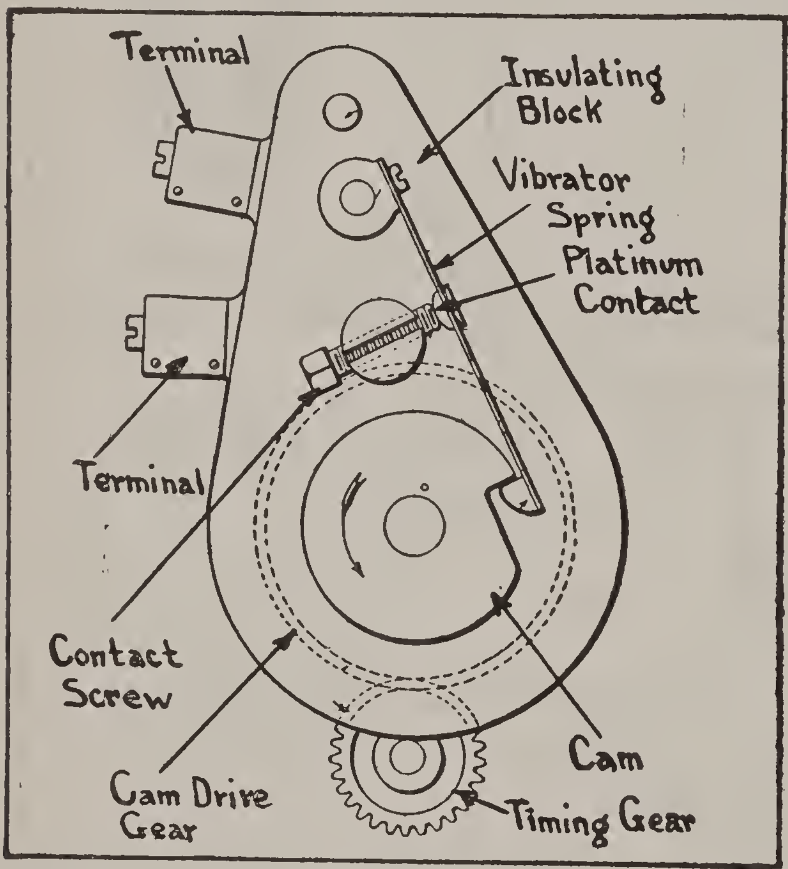


Fig. 143.—Timer Used in Connection With Battery Ignition System for One Cylinder Motor.

In order to produce a spark in the combustion chamber and yet have no leakage of gas, it is necessary to use a special fitting termed "the spark plug" between the points of which the ignition spark takes place. A typical spark plug is shown in section at Fig. 145. The central rod to which the terminal is attached passes through a porcelain body which insulates it from the steel portion that screws into the cylinder. Electrodes extend from the plug body to within

a thirty-second of an inch of the central rod, and it is between these members that the spark takes place. Most of the motorcycle plugs are insulated with mica instead of porcelain, but the general principles of construction are the same in all. The only differences are in points of minor detail such as the size of the thread at the bottom of the plug body and the form of insulation and number of electrodes. Motorcycle spark plugs are provided in two thread sizes, the standard being the metric, which is considerably smaller and finer than the other, which is the regular half inch standard iron pipe thread. The spark plug is usually located in the combustion chamber in such a way that the points are in the path of the fresh gases as they enter through the open inlet valve as shown at Fig. 146. Combination insulations, such as a mica core pressed in a porcelain shell, are used on some plugs, while others are lava or steatite for separating the central electrode from the remainder of the assembly.

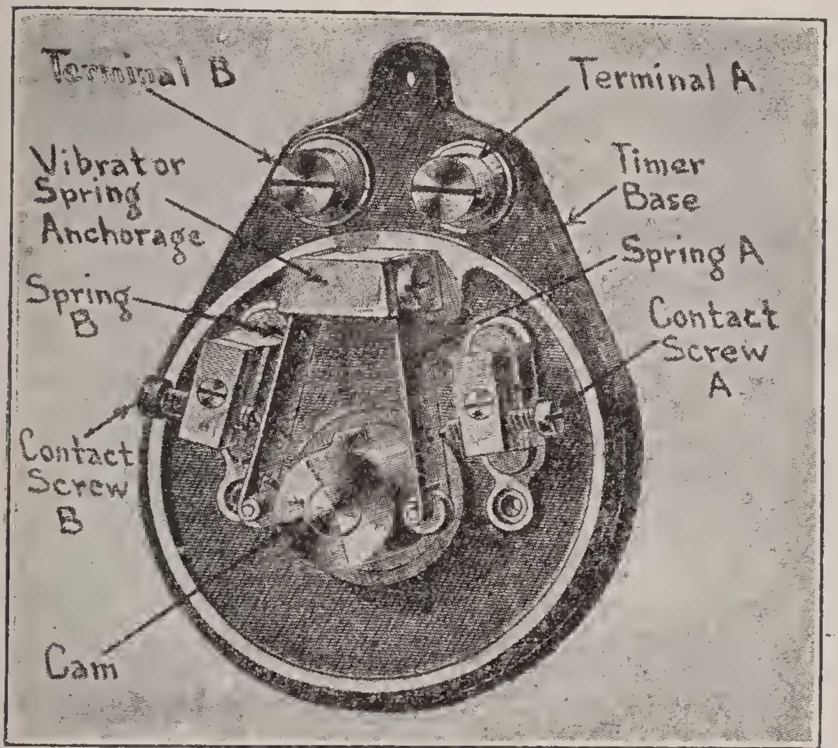


Fig. 144.—Form of Timing Device Employed in Battery Ignition System for Twin Cylinder Motor.

High Tension Magneto Action.—Taking electricity from either a dry or storage battery is comparable to drawing a liquid from a reservoir filled with a certain definite supply. As the demands upon the reservoir increase, its capacity and the amount of liquid it contains become less in direct proportion. Batteries cannot maintain a constant output of electricity for an indefinite period, and their strength is reduced according to the amount of service they give. A mechanical generator of electricity produces current without any actual deterioration or depreciation of chemicals and plates, as is true of a battery. There is some wear present in a mechanical

generator, but this is so small compared to the amount of service it will give that its effect is practically negligible as regards current output.

A simple analogy that will enable one to appreciate the merits of the mechanical generator may be made with a pump system of drawing a liquid from a practically inexhaustible reservoir. As long as the pump is turned it will supply liquid. The same thing is true of a mechanical generator of electricity which will supply current as long as the rotating parts are turned. With batteries, when the engine speed increases, and the demands upon them become greater, the current strength decreases at a time it should be strong. With a mechanical generator of electricity, the current output increases as the speed, and as these devices are usually driven directly from the engine, when this member demands more electricity the mechanical generator will supply it automatically because it is being driven faster.

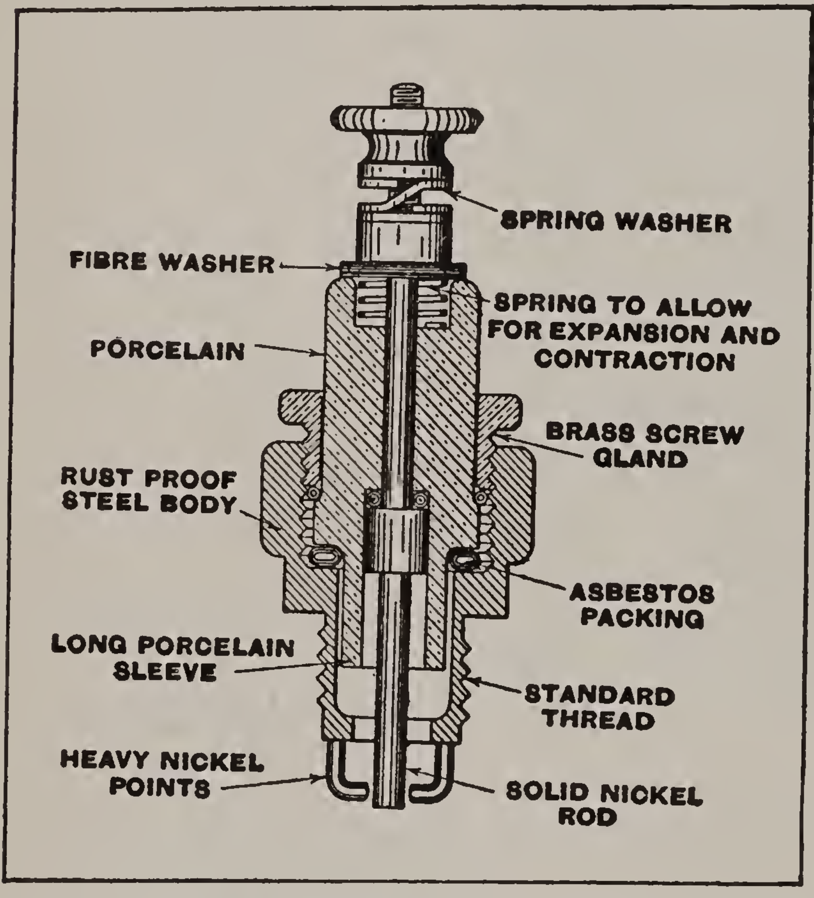


Fig. 145.—Sectional View of Spark Plug With Porcelain Insulation.

The high tension magneto is the form that is generally used in motorcycle ignition systems, and its popularity is increasing among other gas engine users as well. The main advantage of the true high-tension magneto is that it comprises in one device all the elements of the current generating and intensifying devices and all that is needed in connection with a high tension magneto are the spark plugs and the wires by which they are connected to the instrument. A high-tension magneto for a four-cylinder engine is but very little more complicated than one used on a two-cylinder power plant. The only

difference is in the number of contacts in the distributor, and the speed at which the device is driven.

A typical high-tension magneto utilized in connection with a single-cylinder engine is outlined in its simplest form at Fig. 147; and at Figs. 148 and 149, the parts and their proper relation are clearly shown. The armature is a two-pole type having an approximately H section, and it is wound with two coils of wire. One of these is a

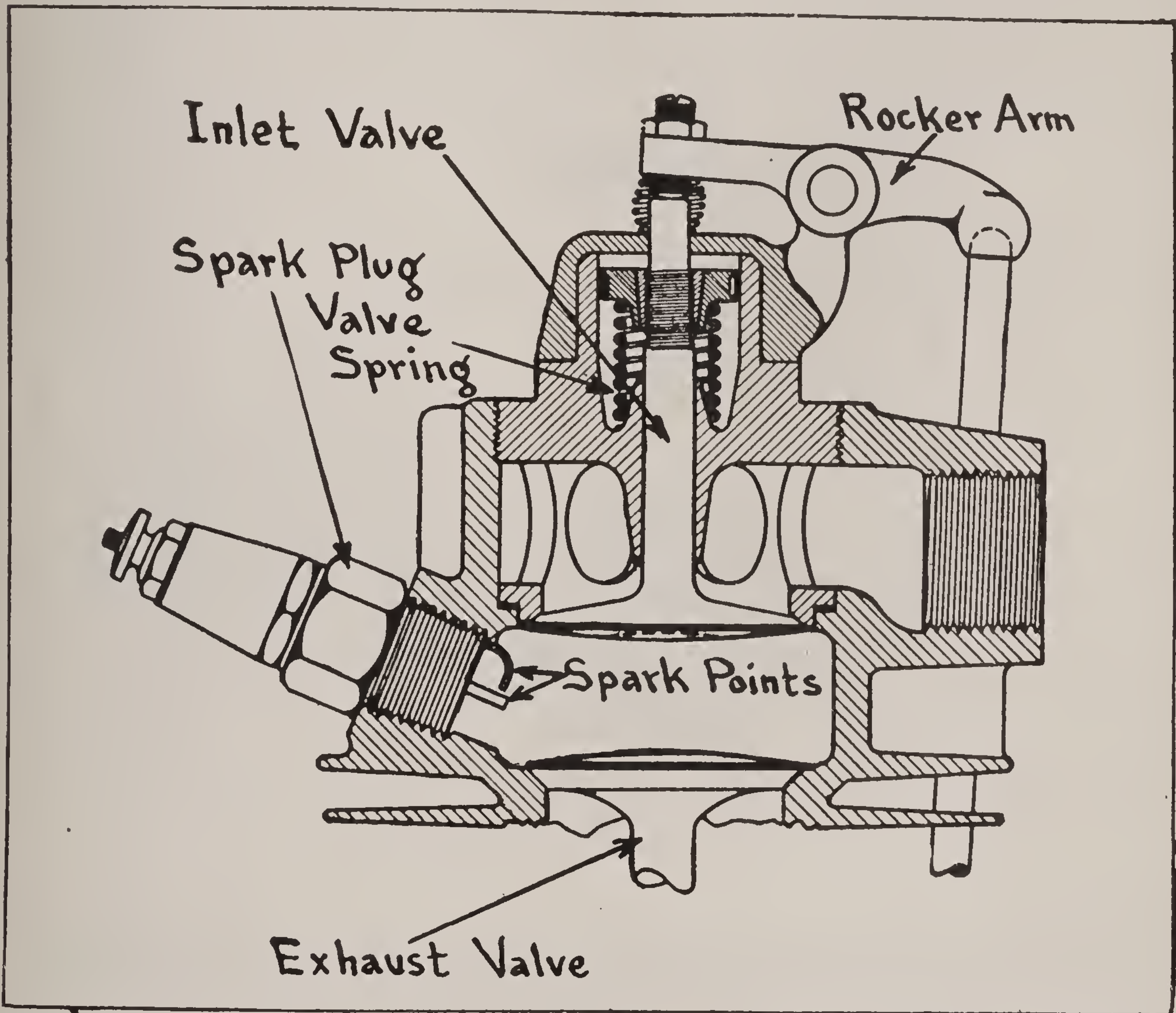


Fig. 146.—Diagram Showing Method of Locating Spark Plug so Points Will be in the Path of the Inlet Gases.

comparatively coarse one corresponding to the primary winding of an induction coil, while the other is a fine winding having many turns that performs the same function as the secondary coil. The armature shaft is mounted on ball bearings to insure easy rotation. The magnetic field is produced by means of two horseshoe magnets attached to iron pole pieces which form the armature tunnel. Mounted on

and turning with the armature is a condenser which is placed in shunt connection with the contact points in the magneto breaker box. The armature is driven by positive chain or gear drive, and it is timed in such a way that the contact points of the magneto contact breaker separate only when a spark is desired in the engine.

The contact breaker, which corresponds to the timer of a battery ignition system, consists of a fixed member which carries one of the platinum contact screws while the movable bell-crank lever carries

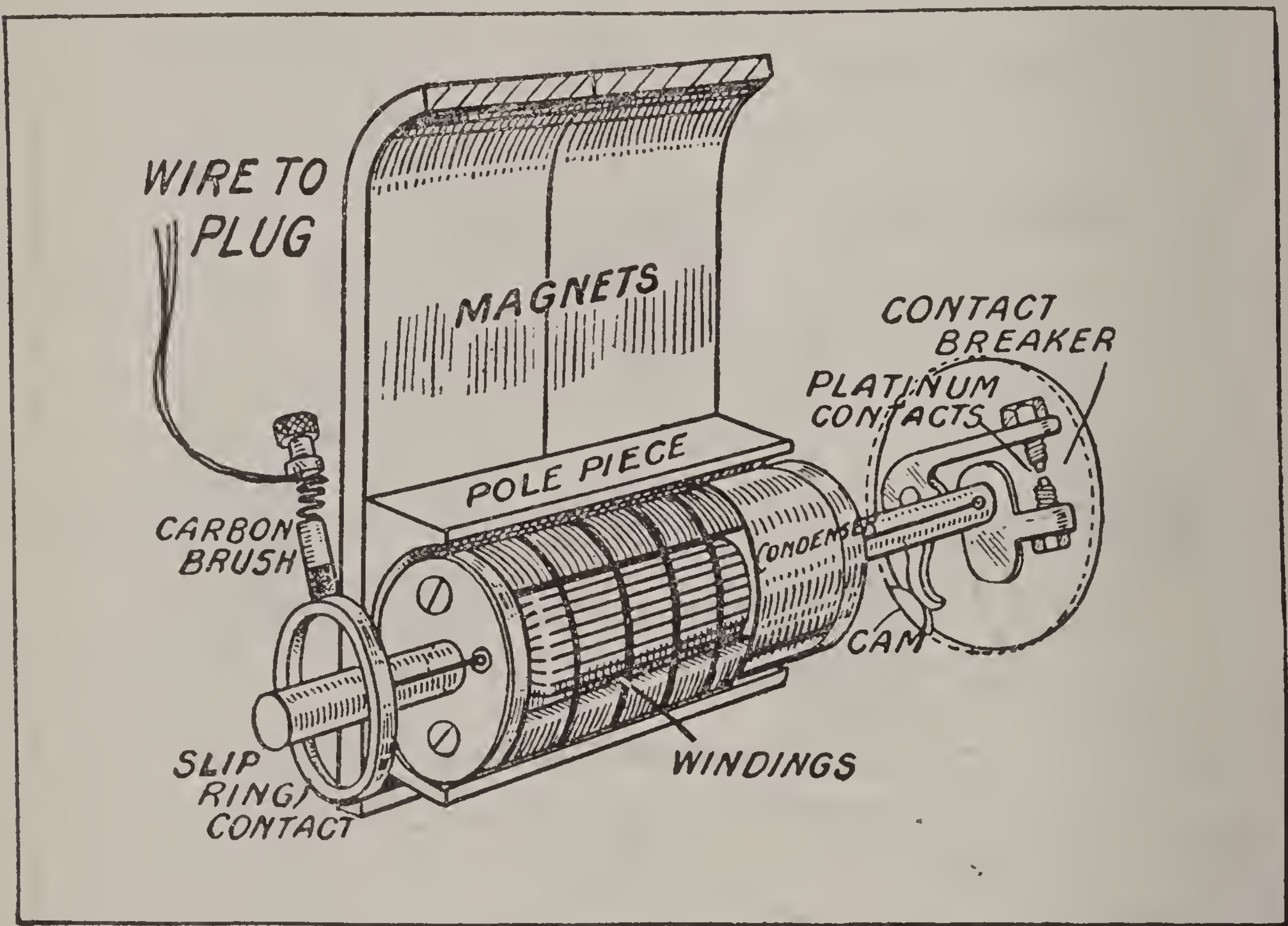


Fig. 147.—Simplified Diagram Showing Arrangement of the Principal Components of True High Tension Magneto.

the other platinum contact. The condenser is used to absorb a surplus current which is due to self induction between the various windings of wire and to prevent the excess current so generated from producing a spark that would tend to burn the contact points as they separate. The safety spark gap is interposed between the high-tension brush and the ground in such a way that any excess current that might injure the windings, if it was allowed to go through the instrument in the regular manner, will be allowed to flow to the ground without

passing through the external circuit. This device performs the same function for the magneto as a safety valve does for a steam boiler, in that it provides a means of escape for excess pressure that might injure the device if no means were provided for its disposal other than the regular channels of distribution.

On a four-cylinder motor, the magneto is driven at crankshaft speed, the contact breaker cams being arranged in such a manner that the contact points separate twice during each revolution of the armature. Every time the contact points are separated a current of electricity leaves the armature by means of a high-tension brush

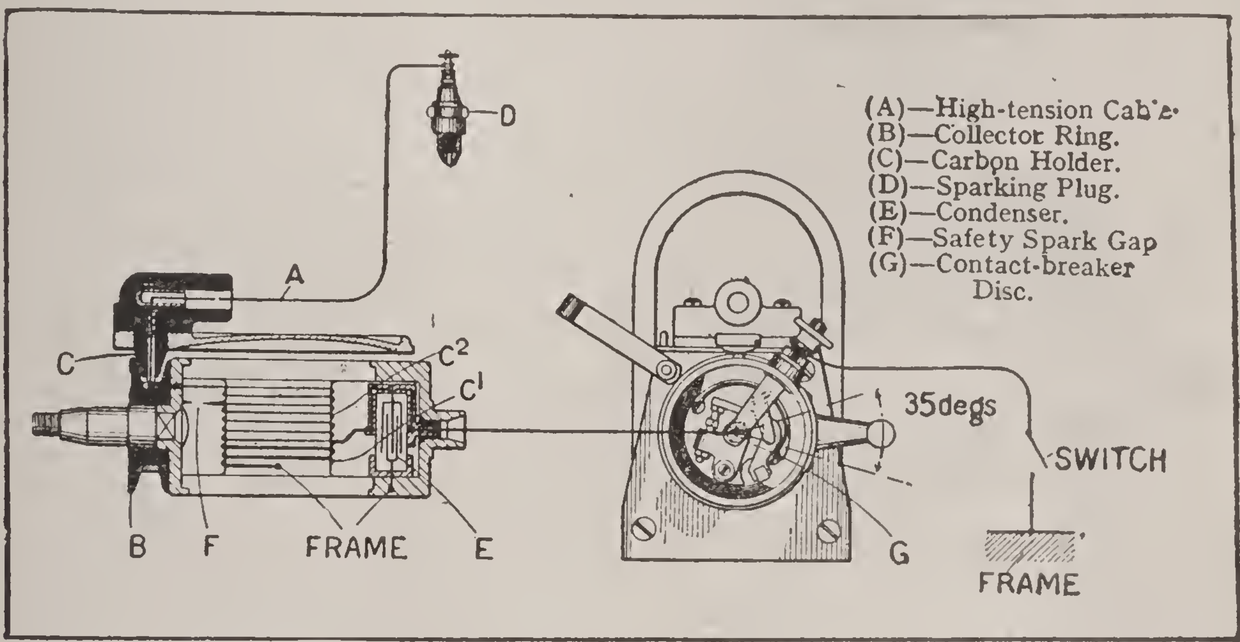
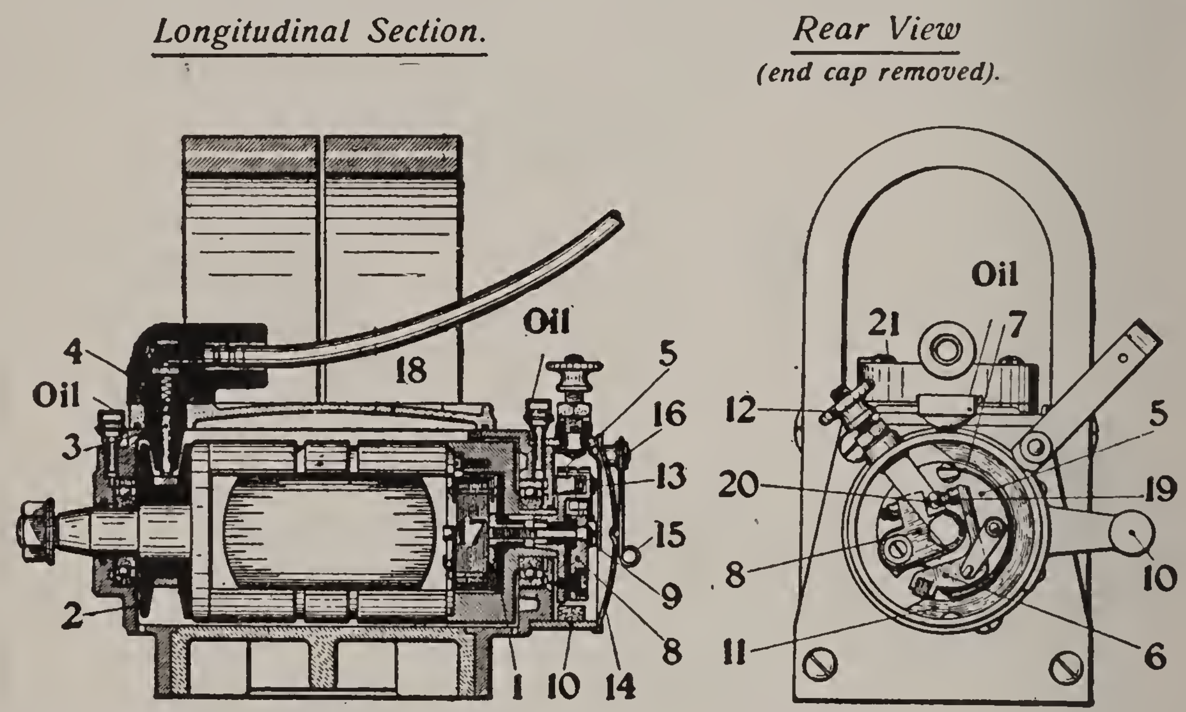


Fig. 148.—Wiring Diagram Showing Method of Connecting Components of the Bosch Magneto.

which bears on the insulated contact ring carried at one end of the armature shaft, and is led to a distributing brush at the center of the secondary current distributing member. The spark plugs are attached to wires which lead to the segments in the distributor, there being one segment for each spark plug. The distributor shaft is revolved at half armature speed by means of gears, and the revolving contact brush makes contact with one of the segments each time that the spark points separate, so the current of electricity is directed to the plug which is in the cylinder about to fire. It will be seen that this device includes the current generating and commutating means as well as the timing mechanism.

Operation of Standard High-Tension Magneto.—Some magnetos intended for twin engines of the V-type have a special arrangement of the pole pieces, as indicated at Fig. 150, so the period of maximum current production will correspond to the point where ignition is desired. The armature of the magneto is driven at the same speed as the cam shaft, and the direction in which the armature is to rotate is indicated by the makers. The angle between the cylinders



1. Brass plate.
2. Slip ring.
3. Carbon brush.
4. Carbon holder.
5. Interrupter disk.
6. Interrupter lever.
7. Spring.
8. Contact piece.
9. Screw.
10. Timing arm.
11. Steel segment.
12. Binding post.
13. Spring.
14. Cover.
15. Spring.
16. Bolt for spring 15.
17. Condenser.
18. Dust cover.
19. Short platinum screw.
20. Long platinum screw.
21. Conical fastening screw for carbon holder 4.

Fig. 149.—Longitudinal Section and Rear View of Bosch Motorcycle Magneto.

of the engine for which the magneto is intended is also indicated, and a magneto cannot be used for the reverse direction to that in which it is stamped or for an angle different from that indicated. As has been previously outlined in the operation of a twin-cylinder V-type four-cycle engine, each cylinder fires once during every two revolutions of the crankshaft, but the two firing strokes are not evenly spaced in the two revolutions, i. e., there is an interval of more than one revolu-

tion between the firing strokes of cylinder 1 and cylinder 2, and an interval of less than a revolution between the firing stroke of cylinder 2 and the following firing stroke of cylinder 1. The revolutions of the crankshaft are therefore divided into a long period and a short period, and, as a rule, cylinder 1 is considered to be that which fires at the beginning of the long period, while No. 2 is that in which a spark takes place at the beginning of the short period. An examination of the interrupter or breaker box of such a magneto, which is clearly shown at Fig. 151, will show that the two segments are marked with the characters 1 and 2, and it will be observed that the dust cover of the magneto also bears these numerals which in that case refer to the two high-tension terminals which are also clearly shown at Fig. 151. When the steel segment marked 1 is operating the interrupter, the carbon brush marked 1 will be in connection with the current-distributing segment on the slip ring, and the secondary current produced at that instant will pass from the magneto to the spark plug connected to that brush. When the engine is installed in a motorcycle, cylinder 1 is the member nearest to the rear wheel and is the one by which the magneto timer is set. The brushes are usually carried in easily removable members as at A, Fig. 152, which shows the brush for a one-cylinder magneto, or at B and C which show the exterior views and section of one of the brushes intended for a two-cylinder magneto.

Magneto Driving Means.—As the magneto will produce current sufficient to overcome the resistance of the air gap at the spark plug only at a certain definite armature position, and as the contact-breaker points must separate coincidently with the attainment of the position of maximum current generation, it is imperative that the magneto be positively driven by the motor to which it is fitted, and by a method of drive that will obviate any possibility of slipping. In this respect, the magneto is different from a dynamo or, in fact, forms of magnetos which deliver a current of low voltage, and which require auxiliary timing and current intensifying appliances before the electrical energy is available for ignition. When the timing device forms part of the magneto, and is attached to the magneto armature, it is imperative that the contact-breaker points separate always at the same time in the cycle of operation.

A simple method of driving a magneto is shown at Fig. 153. In this, a chain extends from a sprocket on the cam-gear shaft to a member of the same size on the magneto armature shaft. The cover of the gear case and chain case is removed to show the relation of the parts to each other. As the chain is protected from abrasive material in the form of dust or grit, and as it is always thoroughly oiled, there will be but little wear or stretching. In this country, the general practice is to drive the magneto through a train of intermediate gears interposed between the cam-timing gears and a suitable member attached to the magneto armature. Some makers, notably Spacke and Pope, drive the magneto by means of worm or spiral gears, and, in some instances, this device may be driven by beveled gearing. It is important to have the drive as direct as possible, because in a system with a large number of gears there is apt to be some back lash develop between the various gear members after the engine has been used for a time, and this may interfere with the accuracy of the spark timing.

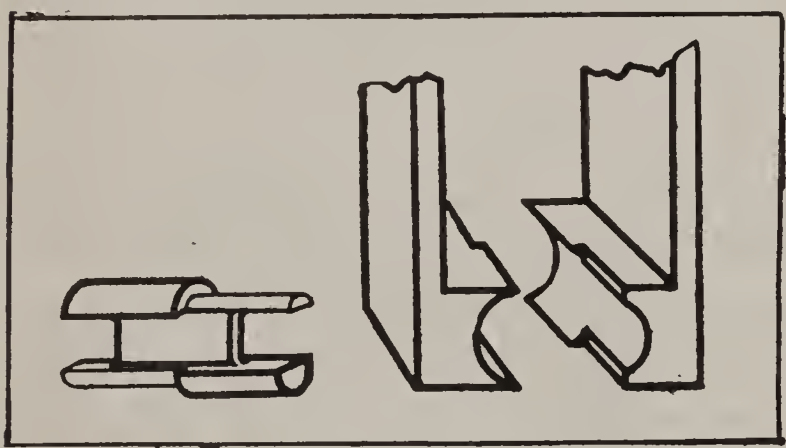
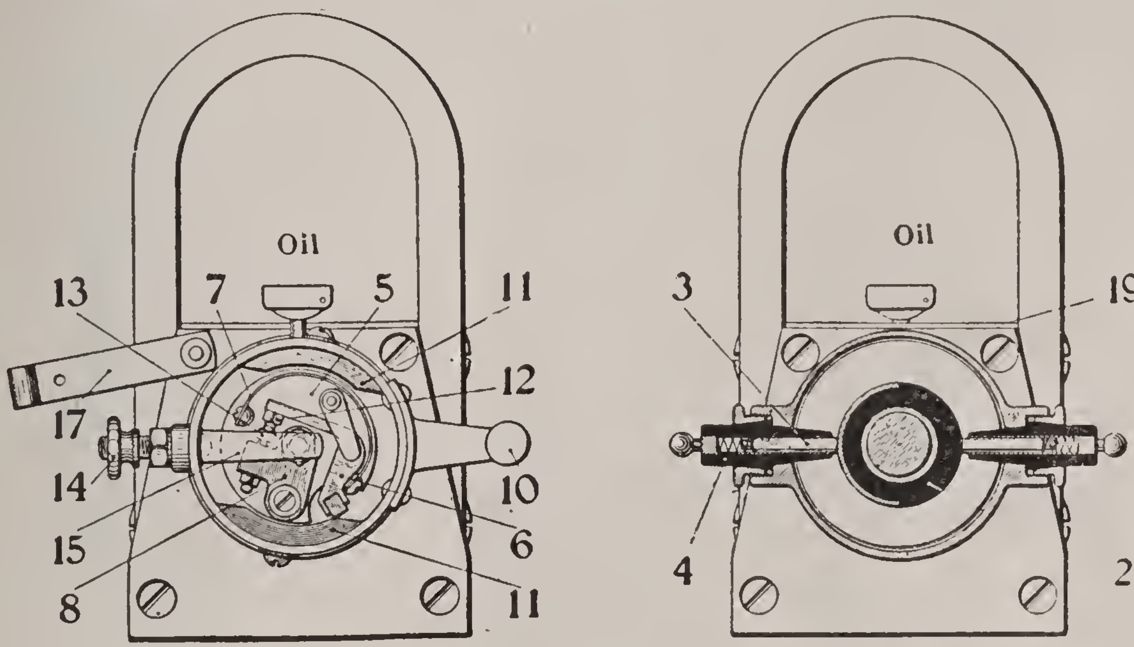


Fig. 150.—Arrangement of Pole Pieces and Armature in Some Magnetos Intended for Two Cylinder V Engine.

Ignition Timing.—An important point in connection with successful operation of the magneto ignition system is that the break between the magneto contact points takes place just when it is desired to obtain a spark in the cylinder. Therefore, in timing a twin-cylinder motor, the engine should be turned over until the piston in cylinder 1 is at the top dead center or upper end of the compression stroke. The position of the piston may be determined by a wire passed through a pet cock or any other opening in the cylinder head, or by a suitable mark on the driving pulley provided by the maker of the engine to indicate that the piston has reached the top of its stroke. The magneto is then bolted to the base prepared for it with the driving gear loose on the armature shaft and the dust cover over the armature removed. The timing control lever attached to the contact

breaker is placed in the full retard position which is done by moving it as far as it will go, in the same direction as the armature is driven. The armature should then be rotated by hand until the cam is separating the interrupter points. The armature should be held firmly in this position and the driving gear is then tightened on the armature shaft. It is imperative that there should be no slippage during this operation. Carbon brush 1 is connected to spark plug of cylinder 1



11. Steel segment.
12. Platinum point on interrupter lever.
13. Platinum point on contact piece.
14. Binding post.
15. Short circuiting spring.
16. Brass cover.
17. Swinging spring.
19. Dust cover.
20. Condenser.

Fig. 151.—Views Showing Contact Breaker and Distributor Arrangement of Bosch Magneto for Two Cylinder Engines.

and carbon brush 2 to the spark plug in the remaining cylinder. Before starting the engine to verify the timing, the dust cover should be replaced over the armature. Timing a single-cylinder engine is, of course, somewhat simpler as there is but one secondary lead from the magneto to the spark plug.

The position of the piston in the cylinder of the Precision engines is shown at the top of Fig. 154, and it is at this point that the contact

points should be just separating, provided that the lever on the contact-breaker case is fully advanced. With the lever fully advanced, the spark points separate before the piston reaches the top of its compression stroke, whereas if the lever on the contact breaker is placed in the retard position the points should not separate until the piston has reached the top of its stroke.

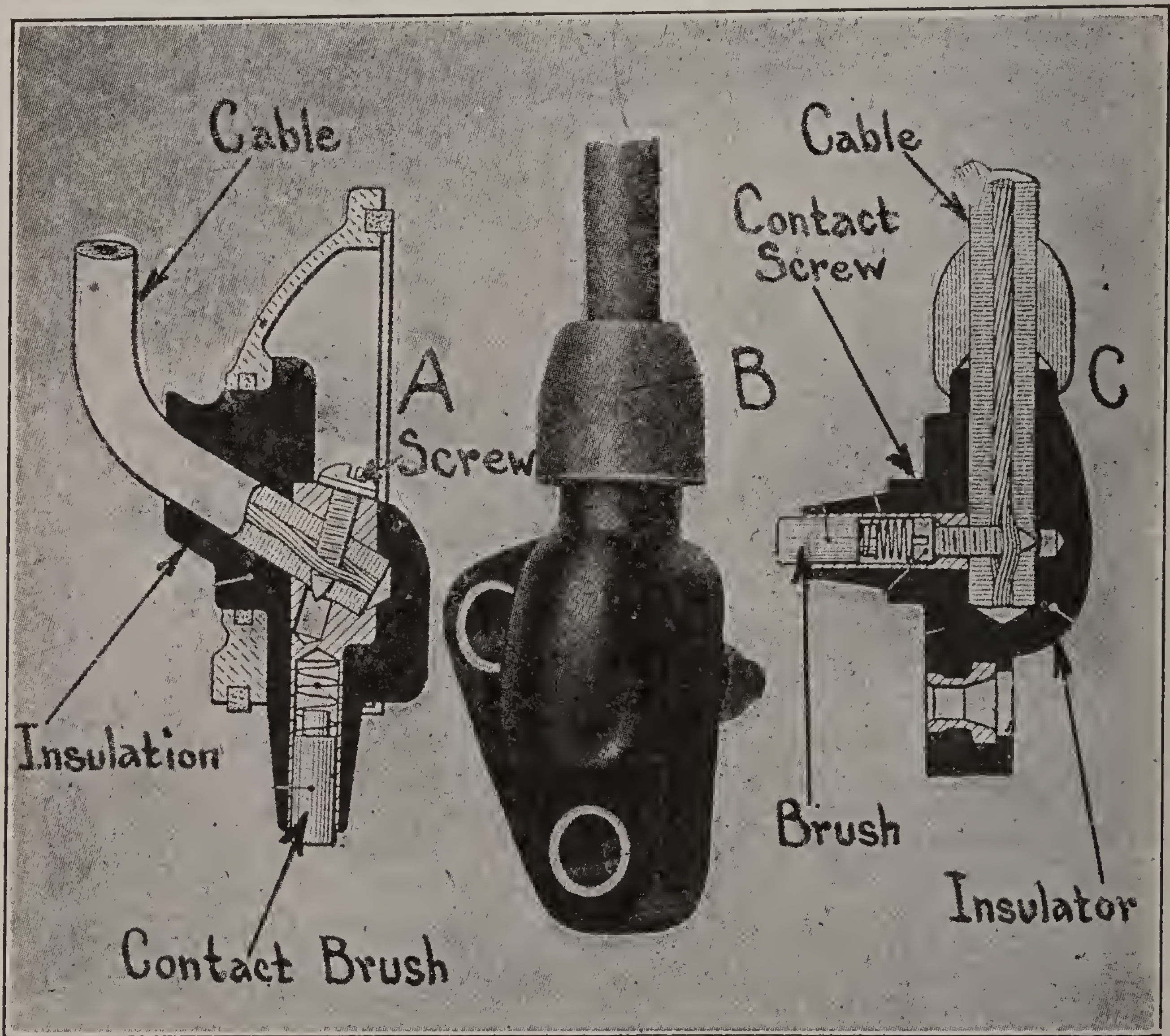


Fig. 152.—Carbon Brush Holders Used in Bosch Magneto, Showing Methods of Making Connections With Secondary Cable.

If a two-cycle engine is to be timed, and the cranks are arranged at 180 degrees, as shown at Fig. 155, the explosions will be separated by equal intervals, and a form of magneto with regular type pole pieces may be employed. The contact breaker arrangement is such that the points are separated at equal intervals because there is no long period or short period as is the case with a V-type, four-cycle

engine. The arrangement of the pistons of a twin-cylinder four-cycle motor in which the explosions are evenly spaced is shown at the top of Fig. 156. A magneto of the same type would also be used with a double-cylinder opposed motor. In the V-type engine, shown at the bottom of Fig. 156, the explosion in cylinder 1 occurs at the beginning

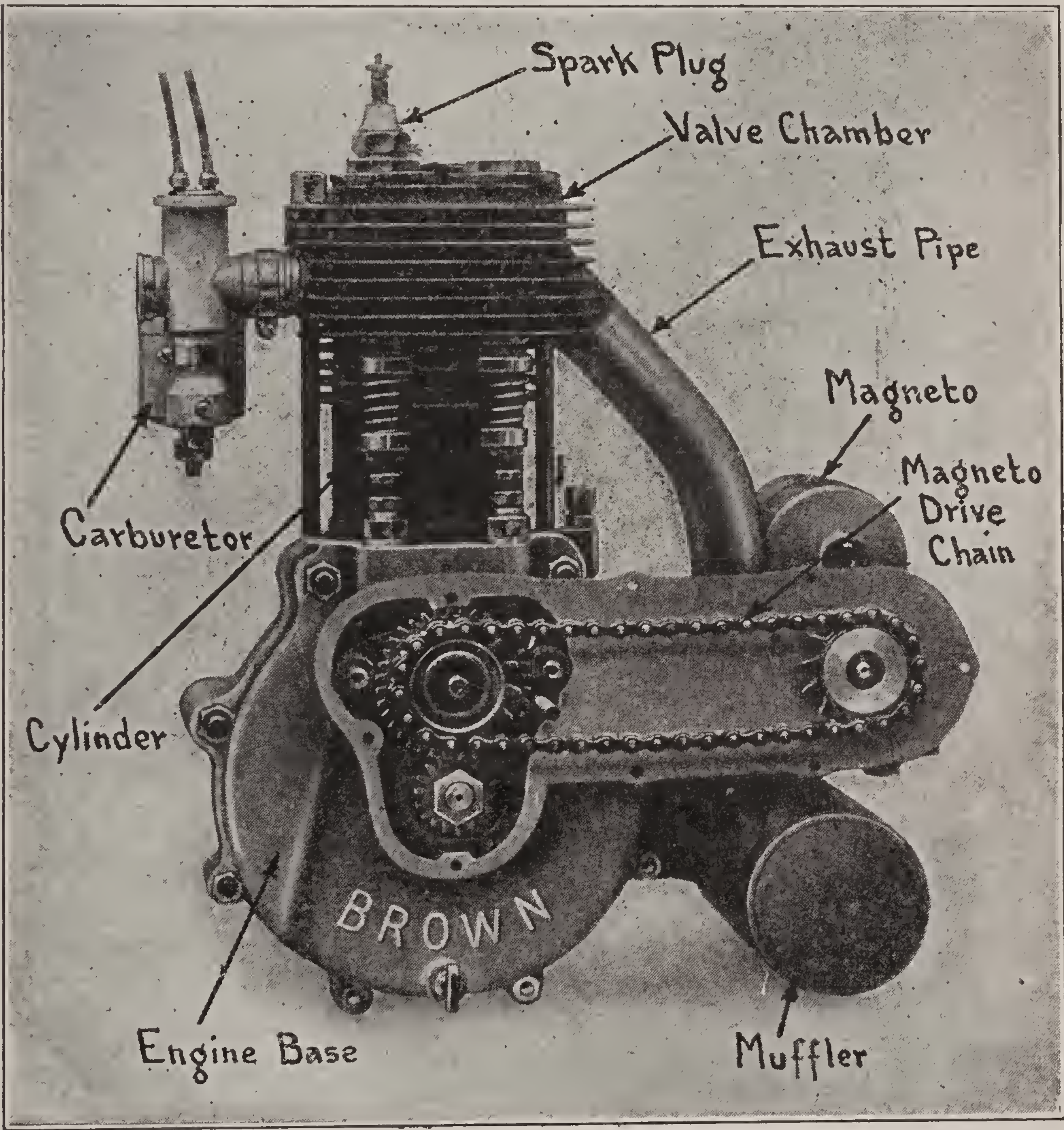
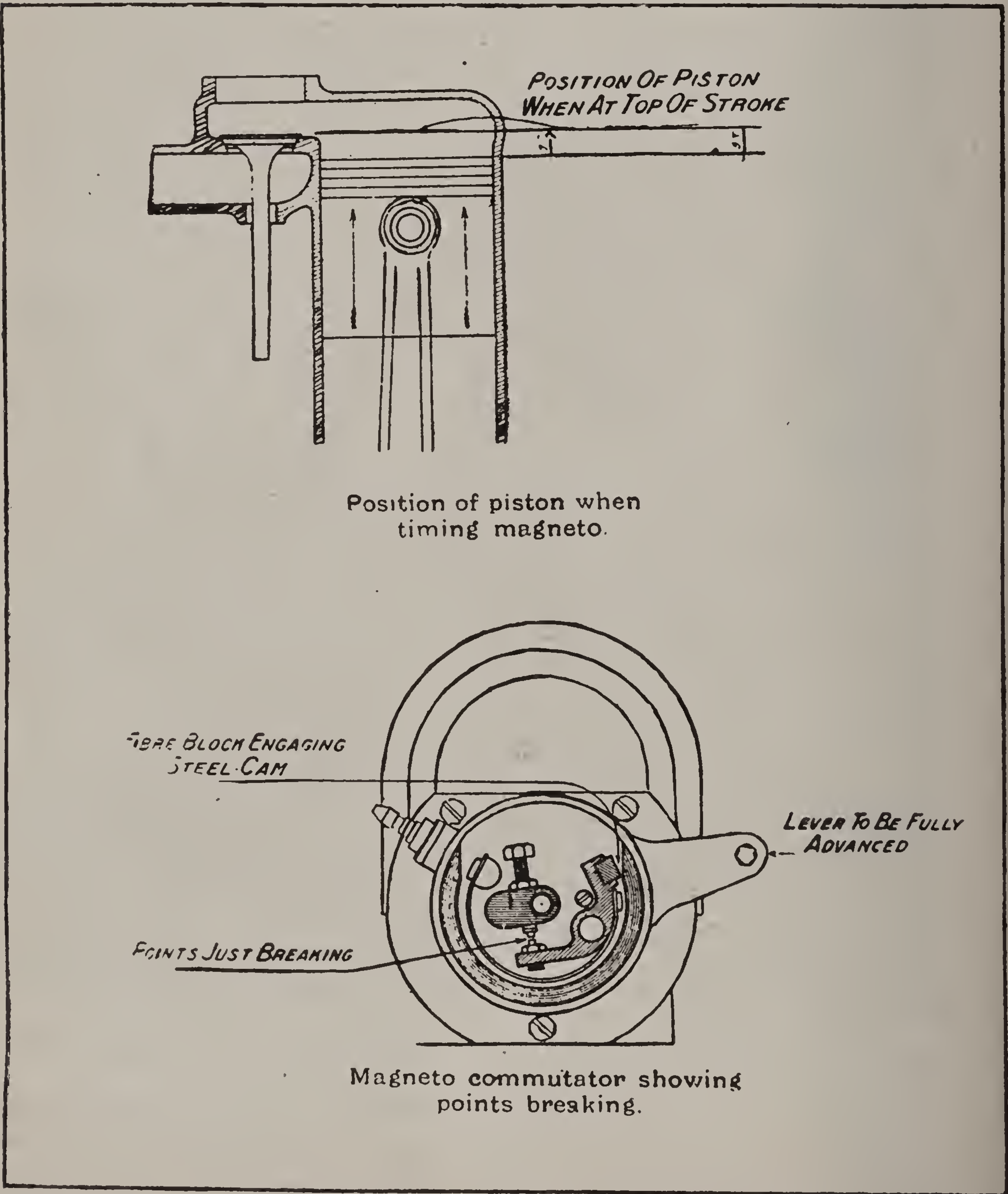


Fig. 153.—Depicting Application of Roller Chain to Magneto Drive.

of the period that is equal to one complete revolution plus the angle A between the cylinder center lines while the explosion in cylinder 2 occurs one revolution minus the angle between the cylinders after the explosion in cylinder 1.

The arrangement of the contact breaker and distributor parts of a four-cylinder magneto is shown at Fig. 157. Just as the cam R is about to separate the contact points, the metal distributing segment of the distributor should be in communication with one of the insulated brushes that are connected to the plugs in the various cylinders; in this case, it would complete the circuit between the



Position of piston when timing magneto.

Magneto commutator showing points breaking.

Fig. 154.—Ignition Timing Diagram.

central distributing member and the brush connected to the cylinder about to fire.

In order to cut off the ignition, the primary circuit of the magneto must be grounded, and this may be accomplished by either of two methods. The one most commonly used in this country is retarding the ignition to an extreme point, at which position of the interrupter housing, a flat spring attached to the primary binding post is brought in contact with a grounded pin located on the magneto end plate. Another method is to connect the binding post to the ground through

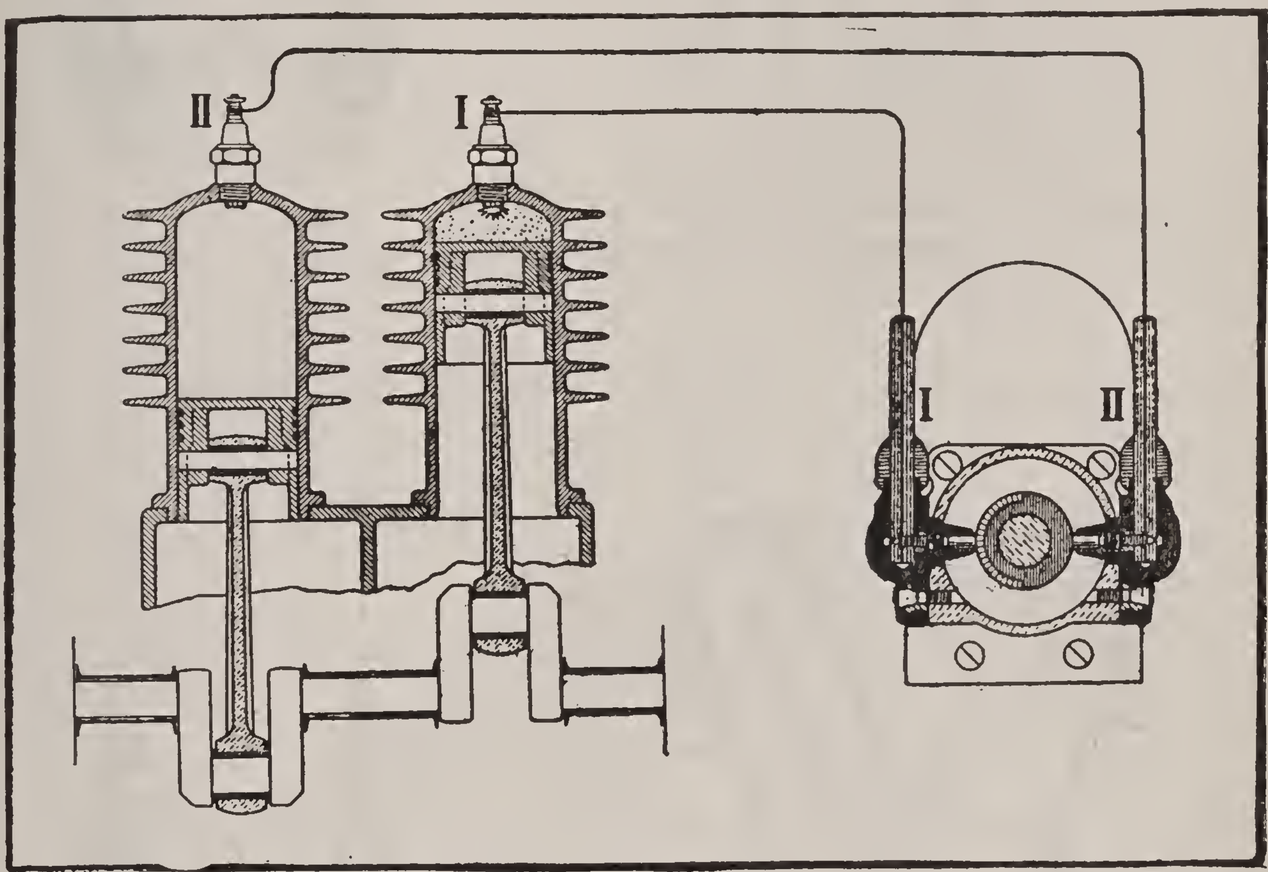


Fig. 155.—Arrangement of Cranks in Two Cylinder Two-cycle Engine to Secure Even Firing Intervals.

the medium of some form of switch, one wire being connected to the binding post and the other switch wire being led to any convenient part of the engine or frame. A cut-out switch adapted for location on the handle bars of a motorcycle is shown at Fig. 158. A block of fiber serves to insulate the contact spring from the handle bar, and when it is desired to ground the circuit, a contact is established between the end of the spring and the handle bar by pressing on the hard rubber knob at the free end of the spring. The action of a

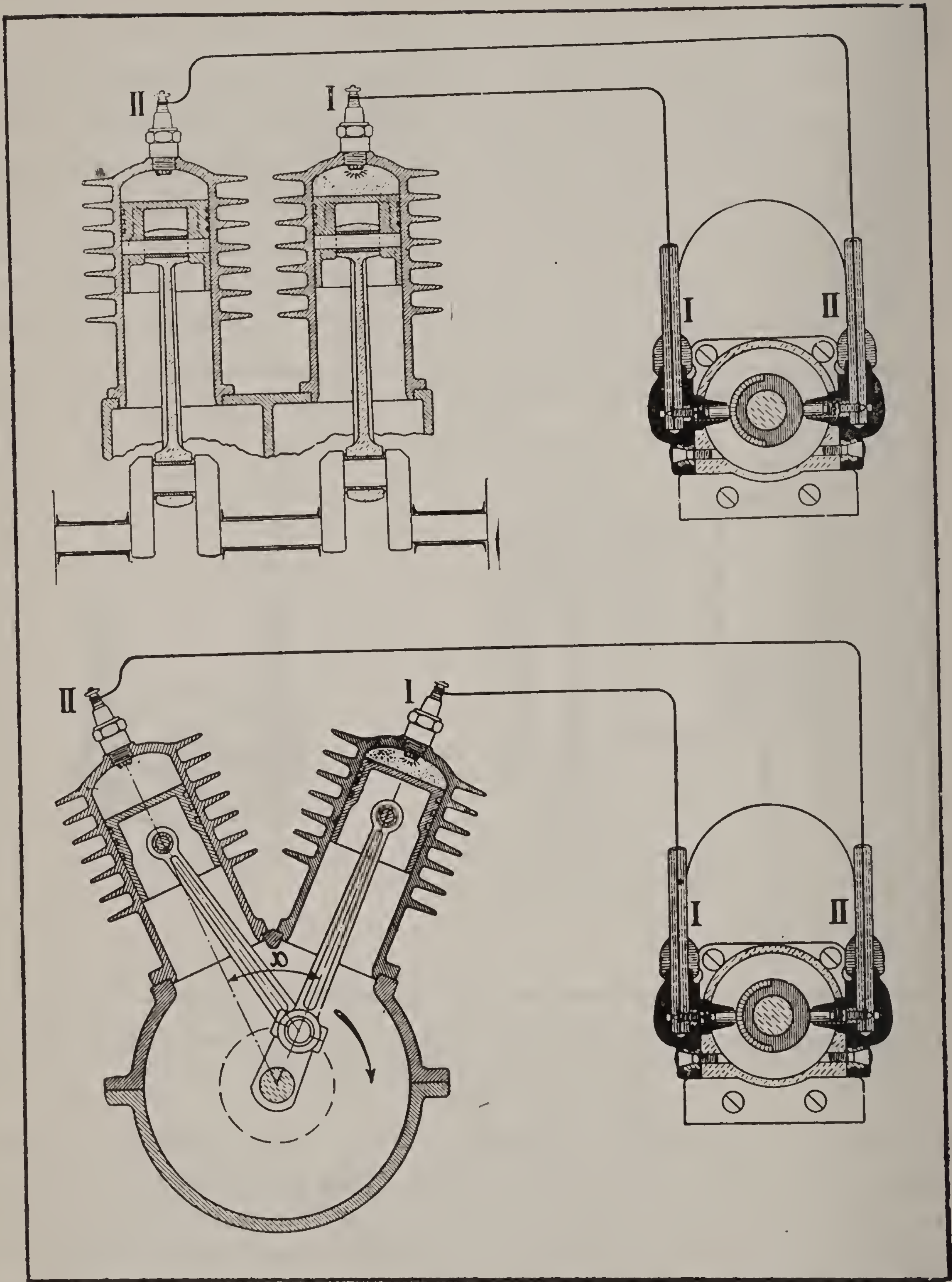


Fig. 156.—At Top, Arrangement of Crank Pins in Two Cylinder Vertical Engine to Secure Even Periods of Time Between Explosions. Below, Usual Arrangement of Crankpin in Two Cylinder Motorcycle Powerplant.

magneto switch is radically different from that of the type employed for battery ignition. With the latter, the current will not flow unless the primary circuit is completed, whereas with a magneto, completing the primary circuit means a discontinuation of current generation. What would be the "on" position in a battery switch is the "off" position in a magneto system.

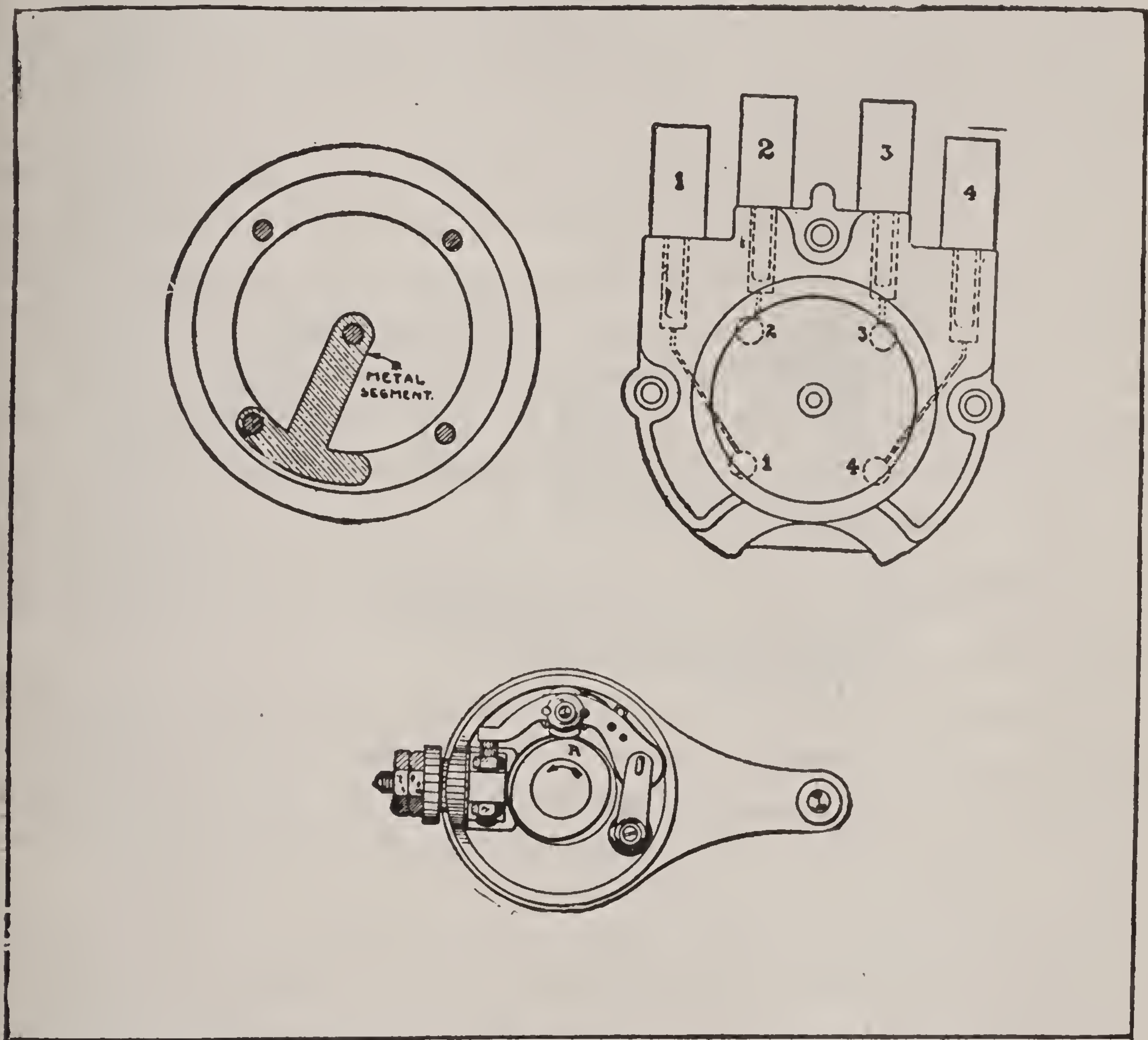


Fig. 157.—Contact Breaker and Distributor of Four Cylinder Magneto.

Detection of Faults.—The following instructions are issued by the makers of the Bosch magneto, and as they cover the ground thoroughly, they are reprinted verbatim:

In case of a fault in the ignition system, the firing will become irregular or will cease entirely. In case of irregular firing, the fault is almost invariably due to a defective spark plug, and if this condition is noticed the spark plugs should be changed.

To locate the cylinder that is misfiring, disconnect the cable from spark plug 1 and crank the engine. If the engine operates on cylinder 2 under these conditions, it shows that the ignition of that cylinder is correct and locates the defect in cylinder 1. However, should no ignition occur, the spark plug of cylinder 2 is defective and must therefore be replaced.

The more common defects of spark plugs are as follows:

First.—Fouling of the plugs, due to the carbonization of the insulation. A fouled plug may be cleaned by the use of a stiff bristle brush dipped in gasoline.

Second.—Too large a gap between the electrodes of the spark plug. The normal spark plug gap should be from 0.5 to 0.6 millimeter (about 1/64 inch), smaller or larger gaps being detrimental to good ignition. If the gap between the spark plug electrodes is too great, the current will discharge across the safety spark gap on the magneto. When the plug is unscrewed from the cylinder, however, the spark will jump across the plug electrodes instead of across the safety spark gap. This does not signify that the distance between the spark plug electrodes is correct, for when the spark plug gap is subjected to the compression that exists in the cylinder the resistance between the points of the gap is greatly increased.

The distance between the spark plug electrodes must therefore be much less than is required when the spark passes in the open air.

Third.—Short circuiting of the spark plug by metallic beads formed across the spark plug gap by the intense heat of the magneto current. The removal of these metallic beads will correct the difficulty.

If ignition fails suddenly, there will probably be a short circuit in the cable connected to binding post 170 and leading to the switch. A difficulty of this sort may be determined by disconnecting the cable from the magneto and testing to see whether ignition is resumed. Should ignition still prove faulty and irregular, the interrupter should be inspected to ascertain if the interrupter lever moves freely, and if the platinum points make good contact.

Should ignition be irregular in both cylinders, the contact points should be examined, which may be done by swinging spring 17 to one side and removing cover 16 (Fig. 151).

The following points should be observed: Screw 9 should be screwed

tight into position; the platinum-pointed screws 12 and 13 should make contact when the interrupter lever 6 is not touching the steel segments 11; the distance between the platinum-pointed screws should be about 0.5 millimeter when the interrupter lever 6 is resting on one of the steel segments 11, and the metal blade, pivoted to the adjusting wrench that is supplied, may be used as a gauge for this distance.

If the parts of the interrupter appear to be in order, screw 9 may be withdrawn and the contact-breaker disk removed complete. The platinum points should be examined, and if they are rough or worn—but only in this event—they should be trued with a fine flat file, or

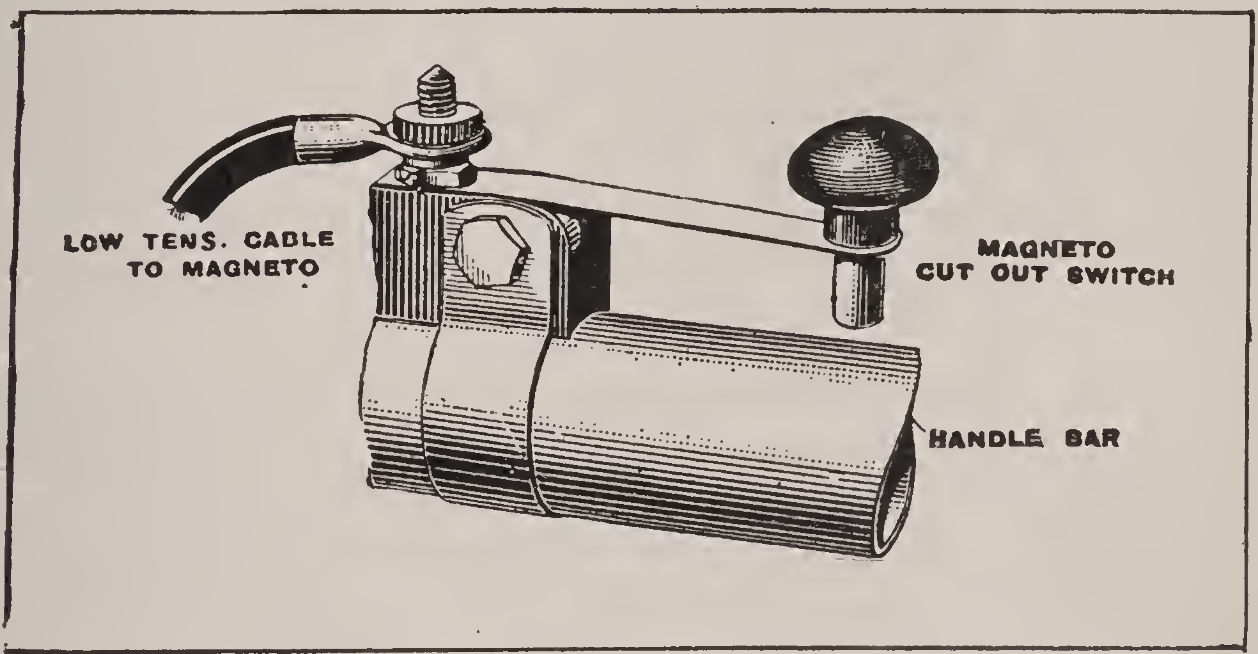


Fig. 158.—Magneto Cutout Switch for Attaching to Motorcycle Handlebars.

with fine emery cloth. If they are oily and dirty, they should be cleansed with gasoline. The surface between spring 15 and the screw 9 should be kept clean.

An investigation as to the cause of trouble may be summarized as follows: First, change the spark plug; second, examine the spark plug cable; third, test for trouble in the switch or switch cable by operating the magneto with the cable disconnected from binding post 170; fourth, examine the interrupter lever for free movement; fifth, dismount the interrupter to examine platinum contacts.

The armature is supported on ball bearings and should be lubricated with a few drops of light oil every 300 to 500 miles, applied to the

oil holes, which can be found at each end of the magneto, covered by hinged brass plates.

The other parts of the apparatus require no lubrication, and care should be taken to prevent the introduction of oil into the interrupter parts. These operate without lubrication, and oil will interfere with their action.

CHAPTER V.

POWER TRANSMISSION SYSTEM PARTS.

Utility of Clutch Defined—Theory of Friction Clutch Action—Types of Clutches—Materials Employed in Clutches—Clutch Location—Typical Motorcycle Clutches—Why Change Speed Gearing is Desirable—Value of Variable Speed Gearing—Variable Speeds by Slipping Clutch—Change Speed Gear Location—Variable Speed Pulleys—Engine Shaft Gear—Countershaft Gears—Rear Hub Gears—Three Chain Systems—Planetary Countershaft Gears—Sliding Gear Type—Power Transmission Methods—Belt Drive Systems—Types of Belts—Standard Belts—Advantages of Drive by Chains—Single Chain Direct Drive—Double Chain Drive—Types of Driving Chains—Combination Chain and Belt Drive—Bevel and Worm Gear Final Drive—Relation of Engine Power to Gear Ratio.

The power transmission group is next in importance to the energy producing elements and much depends upon correct application of the various devices utilized in transmitting the engine energy to the traction member. The efficiency of the motorcycle as a whole depends largely on that of the power transmission system. An extremely powerful and effective motor is of little avail if a large proportion of the power it produces is consumed by friction or transmission losses before it can be applied to the rear wheel to produce useful work. The principal elements of the transmission system of a simple motorcycle are first, a clutching device that permits of releasing the engine from the driving medium or applying the power at will, and second, some system of transmitting the engine power from the clutch to the rear wheels. Many of the 1914 motorcycles include still another element, the variable speed gear, in the power transmission system.

Utility of Clutch Defined.—Practically every motorcycle produced at the present time is fitted with a free engine and clutching device that will permit of running the engine without driving the vehicle. In the early days of motorcycle development, the drive was

direct from the engine crankshaft to the rear wheels without any engine releasing device. It was necessary to start all motorcycles by a preliminary pedaling process which meant that the entire machine had to be pushed along briskly regardless of character of road surface or gradients so the motor would be turned sufficiently fast to start. It was not possible to put the machine on a stand, as is done at the present time, because the absence of the free engine device made it imperative that the machine should acquire a certain amount of momentum before the power was applied. The result was that it required a very strong person to start a powerful twin-cylinder motor fitted to a heavy machine, because, while the machine might start in ten feet, it might require vigorous pedaling for half a city block before the engine was started. When the engine did start, it was apt to race or take hold suddenly because very often the spark would be well advanced or the throttle would be opened to secure easy starting. The sudden application of power was not favorable to the power transmission system and snapped chains or broken belts were not an uncommon result when the power was suddenly applied in this manner.

When a free engine clutch is employed, it is possible to place the machine on a stand and start the power plant with comparative ease because the only resistance to overcome is that offered by the motor itself instead of the rider having to furnish the power to move the heavy machine along the road. After the engine is started, it is possible to release the clutch and disconnect the power from the rear wheels. This enables the rider to take the machine off the stand, keep the engine running, and start off very gradually by utilizing the power of the motor which is delivered to the rear wheel in gradually increasing increments if the friction clutch is let in slowly. Another advantage of the clutch is that it permits of ready control under unfavorable riding conditions such as in traffic, climbing hills, or overcoming poor highway surfaces. Instead of controlling the machine by continually interrupting the motor action, as was the case in the old direct drive days, a twist of the grip on the handle bar or an easy movement of a conveniently placed lever will release the clutch, interrupt the drive and permit the rider to bring his machine to a standstill, if necessary, without stopping the motor.

The control of modern machines is very similar to that of an automobile, and is such an improvement over the old system that its importance is not apt to be realized except by those of us whose experience dates back far enough so we can qualify as veteran motorcyclists. With the old forms of machines, when a patch of sand was encountered or a gradient that did not permit one to "rush" the hill by putting on full speed before reaching the bottom and depend largely on momentum to assist in overcoming the resistance, it was necessary to either get off and push the machine or to endeavor to assist the engine by vigorous pedaling. If perchance one was unfortunate enough to become stalled in the middle of a hill, it was practically impossible to make a new start without returning to the bottom and making another rush to overcome the unfavorable conditions. At the present time, if an engine tends to slow down, due to a patch of sand or other resistance, the rider can slip the clutch a trifle, enable the engine to pick up speed so that it will not stall, and yet deliver enough power to the rear wheel to obtain positive drive.

Theory of Friction Clutch Action.—Clutch forms that are applied to motorcycles are invariably of the friction type, as no progress has been made in utilizing the various hydraulic, pneumatic, or magnetic clutches that have been offered at various times by over-sanguine inventors. The friction clutch has proven to be the most satisfactory, and has received wide practical application in its various forms. The important requirement of a clutch is that it will be capable of transmitting the maximum power of the motor without any loss due to slipping when fully engaged. A clutch should be operated easily and require but minimum exertion on the part of the operator. A clutch should be gradual in action, i. e., when it takes hold, the engine power should be transmitted to the driving member in a gradual and uniform manner or the resulting shock may result in serious injury to some part of the driving mechanism. It is also imperative that a clutch release at once when desired, and that there be no continued rotation of parts, which insures that the drive will be interrupted positively when the clutch is disengaged. In considering the design of a clutch, it is very desirable that this component be located in an accessible manner, which is a good feature, as it permits of easier

removal for inspection, cleaning and repair. It is imperative that some form of adjustment be provided so a certain amount of wear will be compensated for, without replacing any expensive parts. A simple design with a minimum number of operating parts is more to be desired than a more complicated form which may have some minor advantages, but which is much more likely to cause trouble.

To illustrate the transmission of power by frictional adhesion of various substances with each other, one can assume a simple clutch form consisting of two metal discs or plates in contact, the pressure keeping them together being due to the weight of one member bearing upon the other. If the discs are not heavy, it will be found easy to turn one upon the other, but if weights are added to the upper member a more decided resistance will be felt which will increase directly as the weight on the top disc and consequently the total pressure augments. It is possible to add enough weight so it will be difficult to move one plate without producing a corresponding movement of the other. If one of these plates is mounted on an engine shaft, and the other applied to the transmission member so that a certain amount of axial movement is possible, and the pressure maintaining contact was obtained by springs instead of weights, one would secure a combination capable of transmitting power, inasmuch as the spring pressure applied to one disc would force it against the other, and one shaft could not revolve without producing motion of the other.

Types of Clutches.—Three main forms of friction clutches have been employed in motorcycles, and these, in the order of their importance, are disc, plate, band and cone designs. The disc clutch is the most popular because it is a compact form, and in its simplest design it would consist of a casing driven by the engine with a series of discs attached to it, and another member carrying another set of discs that was connected to the driving wheel by suitable gearing. The discs attached to the case are distinct from those carried by the driven member, and driving contact is maintained between the two by steel springs. It is possible to house a multiple disc clutch in an oil-tight casing, which means that it is possible to slip this form of clutch much more than the cone or band types, which for the most part operate without lubricant. A large number of small diameter discs are employed to transmit the power, and the required contact area

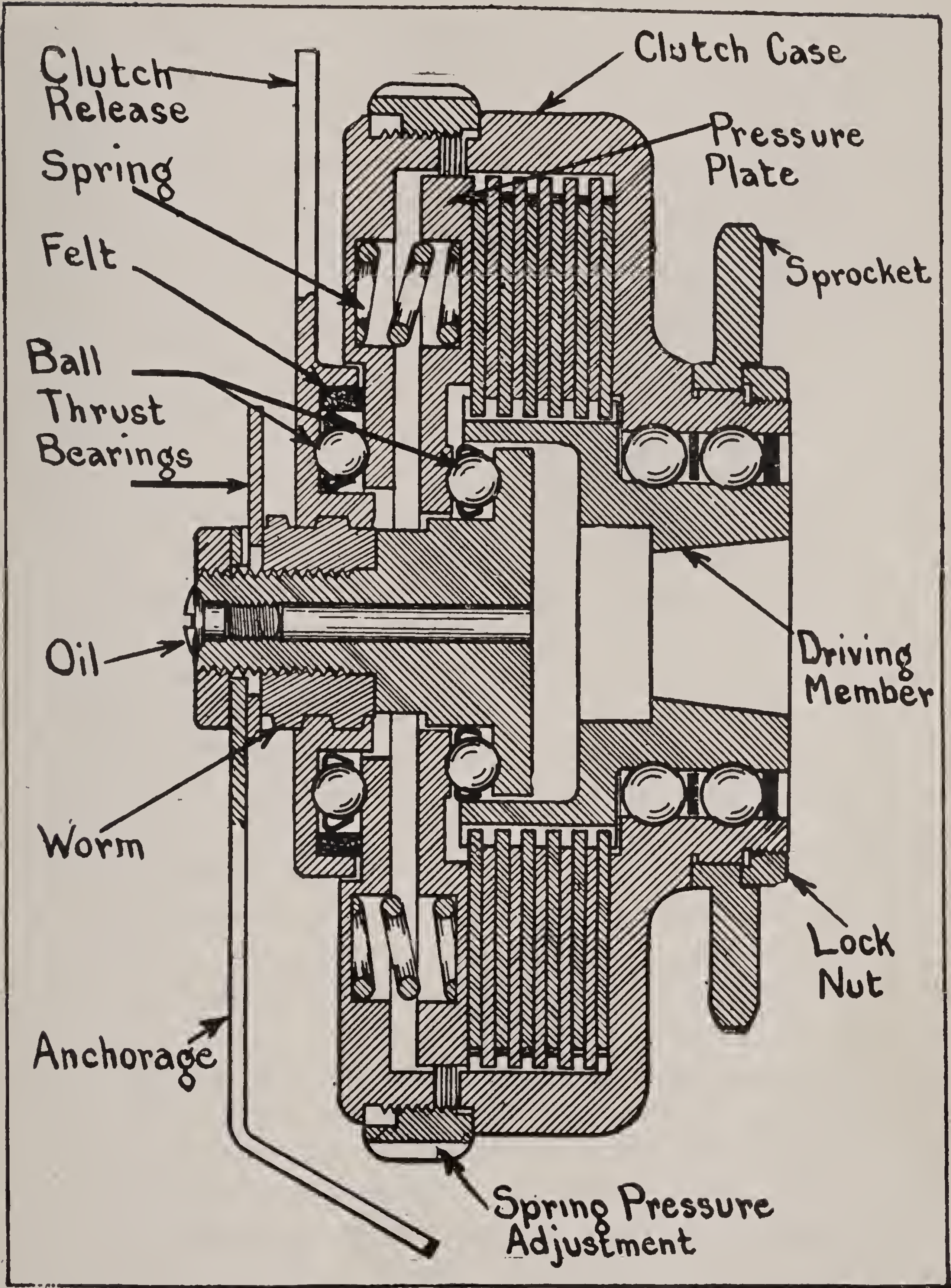


Fig. 159.—Sectional View of the Eclipse Engine Shaft Multiple Disc Clutch.

is obtained by the use of a number of comparatively small surfaces, instead of two larger ones, as is the case with the cone or band clutch.

The type of multiple disc clutch that is the most widely adopted is shown at Fig. 159, and, while the form outlined uses discs of the same material, in some forms of clutches one set of discs will be of steel while the other will be of phosphor bronze. The drive from the engine shaft is taken by a driving member keyed to it, and one set of plates is securely fastened to this member. The remaining plates are attached to the clutch case and revolve with it and the drive sprocket that goes to the rear wheel is also secured to the clutch case. The pressure to maintain the plates in frictional contact is obtained from a series of coil springs which act against a pressure plate which, in turn, bears against the disc assembly. The use of oil in this form of clutch is of advantage because it not only promotes easy engagement by interposing an elastic cushion between the metal plates and thus prevents too rapid engagement, but it also reduces depreciation when the clutch is released or the discs are slipping by each other because of its value as a lubricant. Owing to the small diameter of multiple disc clutches, the inertia of the driven member or tendency to rotate when disengaged is less than in a cone clutch or band form of larger diameter. The spring pressure is usually sufficient to squeeze the oil from between the plates as soon as the clutch is fully engaged, and a metal to metal contact is then obtained. In fact, if the lubricant was retained between the surfaces, the clutch would slip, but as it is gradually forced out and there is a certain amount of slipping as long as any of the lubricant remains, this feature insures that the power will be applied in a gradual manner even if the clutch is carelessly operated.

The cone clutch in its simplest form consists of a female member in the form of a saucer-shaped metal piece, and a male member, which is a truncated cone, which fits into it, and a spring or leverage to maintain frictional contact between the surfaces. The male member is usually faced with some frictional material to secure better driving power through superior frictional adhesion. Band clutches may be of two forms. The one that is most generally used in connection with planetary speed change gearing consists of a steel band lined with frictional material that contracts against a drum or an internal band which is expanded inside of the drum. The internal form is generally used when it is desired to keep both parts in motion, as

for instance in transmitting power between the shaft on which the expanding band is attached to the drum against the inside periphery of which it bears. The constricting band clutches are generally used in the form of a brake to restrain the motion of a planetary gear carrying member in order that the gears will transmit power.

Materials Employed in Clutches.—One of the important points in clutch design is to secure as much frictional adhesion between the parts as possible. The transmitting efficiency of a clutch will vary with the coefficient of friction (which means the amount of adhesion) under pressure and, of course, the more friction between the surfaces for a given amount of spring pressure the more suitable the clutch will be for transmitting power. A metal usually forms one frictional surface in all forms of clutches, and some types, notably the multiple-disc forms, have all friction surfaces of metal. The metallic materials generally used are cast iron, aluminum and bronze castings, and sheet steel and bronze in the form of thin stamped discs. The non-metallic frictional materials often employed are leather, asbestos fabrics, textile belting and cork. Leather is the best lining or facing for clutches where the friction area is large and where the clutch is not apt to be slipped much. When used, it must be kept properly lubricated and soft because, if it becomes dry, it will engage very suddenly and promote harsh clutch action. Care must be taken not to supply too much oil, because the co-efficient of friction will be reduced to a low point and the surfaces will slip by each other. Chrome-tanned leather is generally used because it has good wearing qualities and, in addition to being a very resilient material, it possesses a very satisfactory degree of frictional adhesion when pressed against a cast iron member. Oak-tanned leather is also used for clutch facings. A clutch for motorcycle use should be faced with asbestos fabric rather than leather, unless it formed a part of a two-speed gear, which would not require slipping the clutch to any extent. These asbestos fabrics, of which raybestos is one of the best known, are used to some extent as a facing in multiple disc clutches of the dry plate type. Cork is sometimes used in connection with metal surfaces in the form of inserts which are compressed into suitable holes machined to receive them. Cork has a high coefficient of friction, and is not materially affected either by excessive lubrication or lack of oil. The cork inserts

promote gradual engagement and possess very desirable wearing qualities. Metal to metal surfaces are the rule in multiple disc or plate clutches of small diameter where a multiplicity of surfaces are depended on for driving, but when a lesser number of plates of larger diameter are used, cork inserts or an asbestos fabric facing are invariably provided on one set of plates.

Clutch Location.—There are three points in a motorcycle where it is possible to apply a friction clutch, these being on the engine crankshaft, on a countershaft, or in the rear wheel. The faster the parts of a clutch turn, the smaller in diameter they can be to transmit the same amount of power, and for this reason the engine shaft is favored by a number of makers. Sometimes the clutch is attached directly to the crankshaft extension, to which the sprocket would normally be fastened in a direct or countershaft drive construction, and at the present time the engine shaft location is growing in favor. The most general location, which may be considered typical of standard practice, is at the crank hanger, which involves the use of a larger clutch on account of the lessened speed of that member. If the clutch is housed in the rear hub it must be even larger, i. e., it must have a greater number of discs if it uses the same spring pressure as either an engine shaft or countershaft clutch or it must employ higher spring pressure if it uses the same number of discs as would ordinarily be used in either of the other locations. It is contended by those who favor the rear wheel location, that while the clutch parts must be larger, they are also more substantial and stronger, and owing to the reduction in speed the surfaces are not apt to wear as rapidly when they slip by each other with the clutch partially released as would be the case in an engine-shaft clutch or even the countershaft type. The latter form is a compromise between the two extremes, the engine-shaft clutch on one hand and rear hub form on the other.

Typical Motorcycle Clutches.—The multiple disc clutch shown at Fig. 159 is the engine-shaft type, and is very compact as well as effective. When the springs are compressed to release the clutch by drawing the pressure plate away from the disc assembly; the outer casing which carries the driving sprocket revolves on a double row ball bearing, the inner race of which is formed by the driving member attached to the engine shaft. To release the clutch, a suitable lever,

provided with an internal spiral thread, is rocked on a fixed member which has an external spiral thread. This fixed member communicates with the pressure plate through the medium of a ball thrust bearing, and as the clutch release lever is moved, the spiral thread or worm produces a lateral displacement of the pressure plate.

Another form of engine-shaft clutch is shown at Fig. 160. In this,

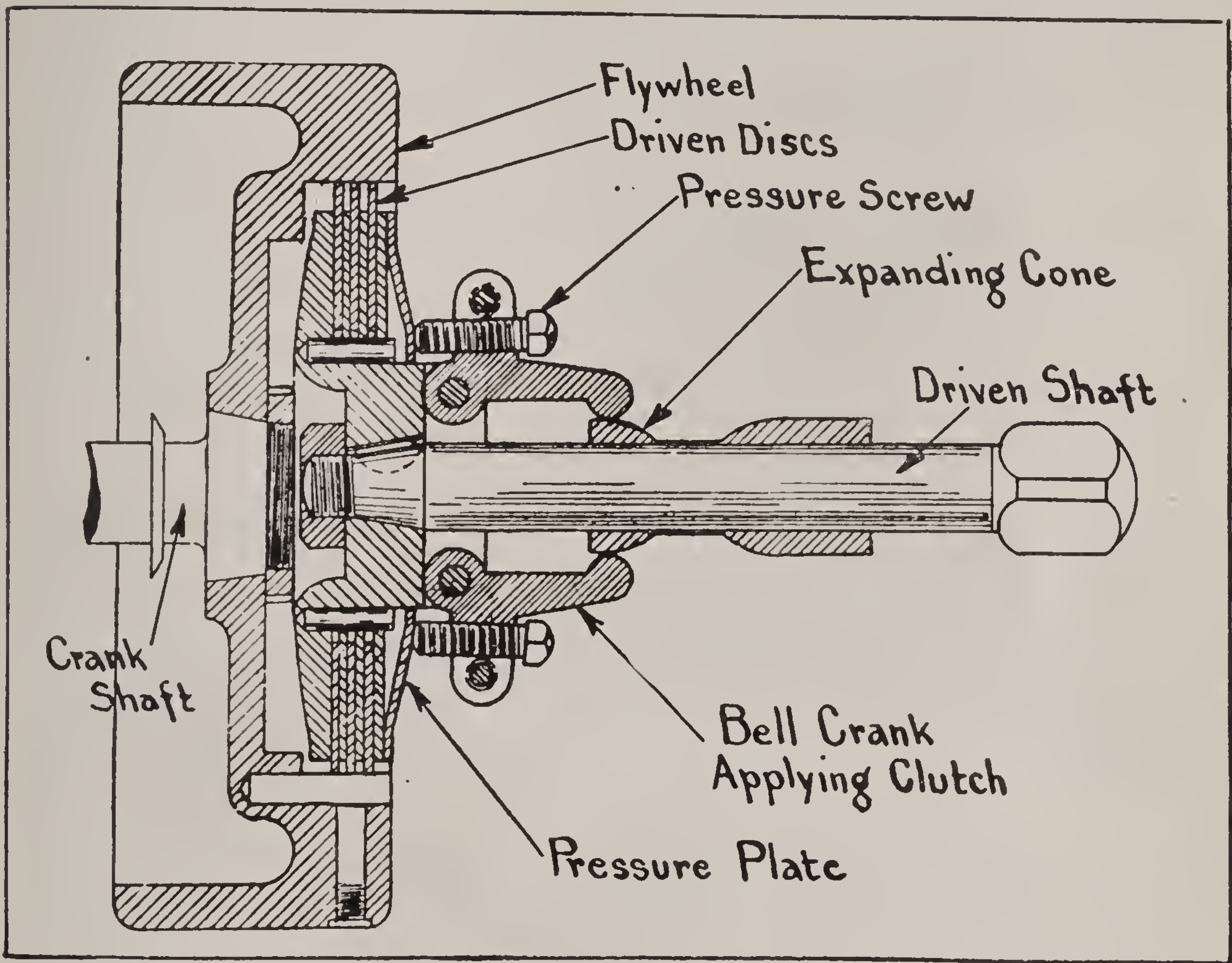


Fig. 160.—Sectional View of the Pierce Cone Actuated Multiple Disc Clutch.

the clutch is applied by a series of bell cranks which are provided at one end with an adjustable pressure screw bearing against the pressure plate of the disc assembly, and a bearing portion at the other end which works against a movable cone member that applies the clutch by spreading out the bell cranks and squeezing the driven and driving disc assemblies together.

The Eclipse countershaft clutch shown at Fig. 161 has been widely specified, and is the same in general construction and principle of operation as the form shown at Fig. 159, except that the drive from

the engine goes to a sprocket attached to the clutch casing while the driving sprocket is secured to the inner member, which in this case is the driven instead of the driving portion of the clutch. The releasing means is similar to that previously described and is by spirally threaded members.

The countershaft clutch shown at Fig. 162 is used on Indian motorcycles, and while it is a multiple disc form it employs friction facing

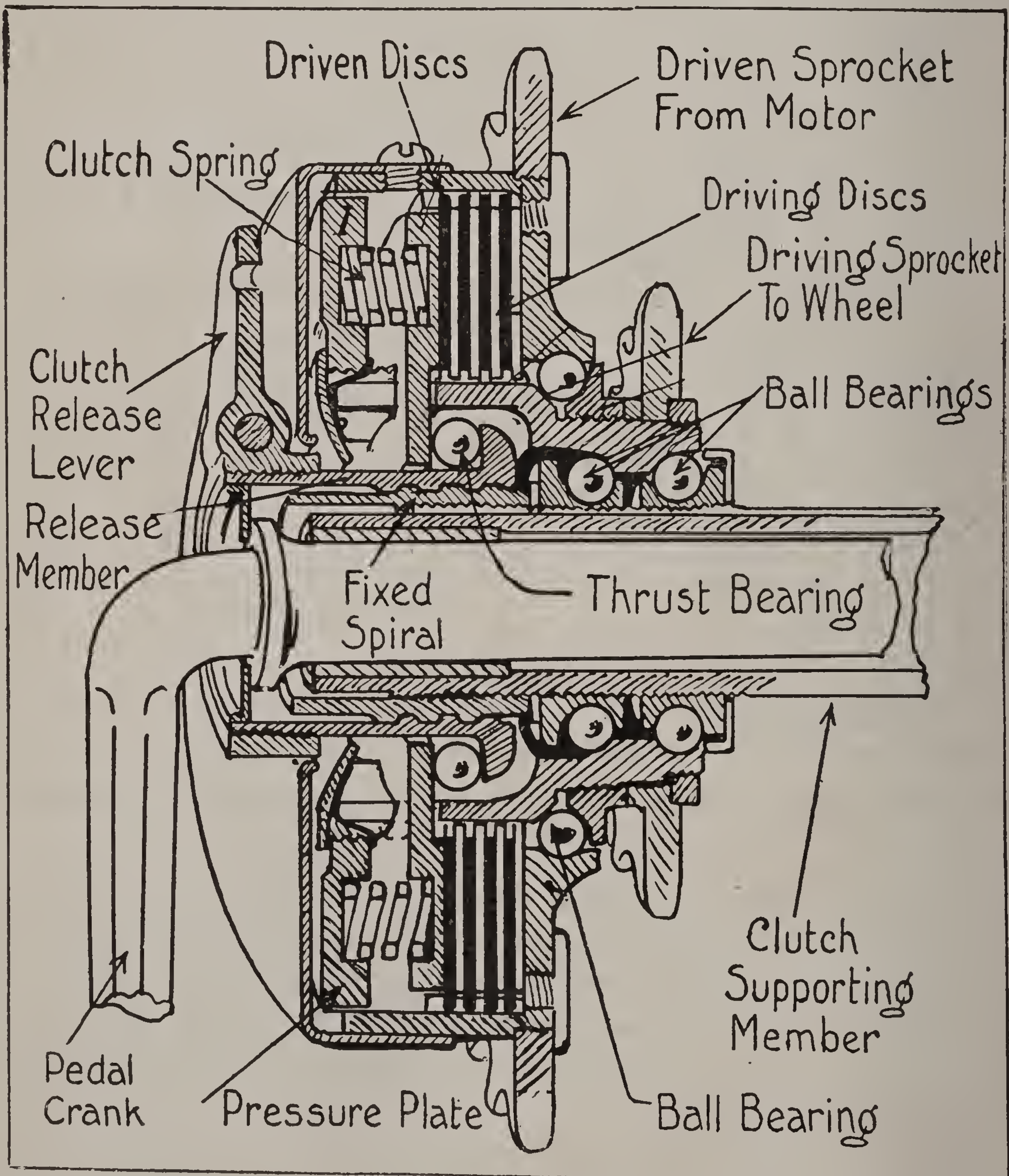


Fig. 161.—Sectional View of the Eclipse Countershaft Type Free Engine Clutch.

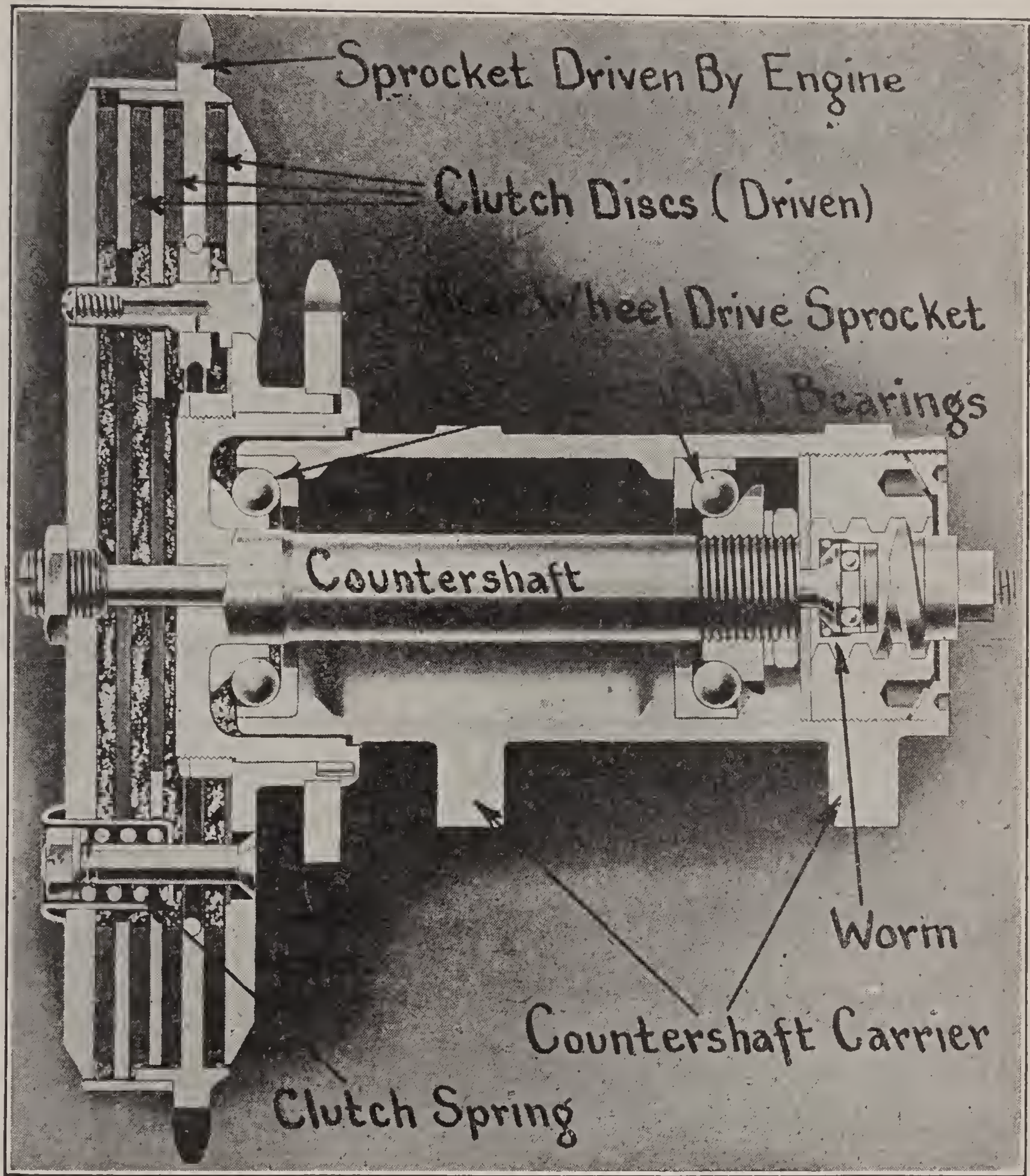


Fig. 162.—Countershaft Type Multiple Disc Clutch Used on Indian Motorcycles.

on part of the discs instead of utilizing the metal-to-metal contact. This view is valuable also, in showing the method of application of a countershaft clutch assembly in a carrier member adapted to fit the crank hanger box of the frame. The method of releasing this clutch is similar to that employed in the other forms as it involves a movable worm operating in a fixed, internally threaded member. The angle of the threads on the worm is such that as it is rocked in the nut it

advances and pushes against a rod passing through the center of the countershaft and securely attached to the pressure plate which forms the outer member of the clutch case. The pressure plate is normally kept in contact with the clutch disc assembly by small coil springs which exert their pressure against cups carried by the pressure plate. The springs are compressed to a suitable degree by adjustable nuts carried on bolts that hold the inner and outer clutch members together and which tend to clamp the disc assembly between them. The large sprocket is driven by the engine, while the small one is employed to drive the rear wheel.

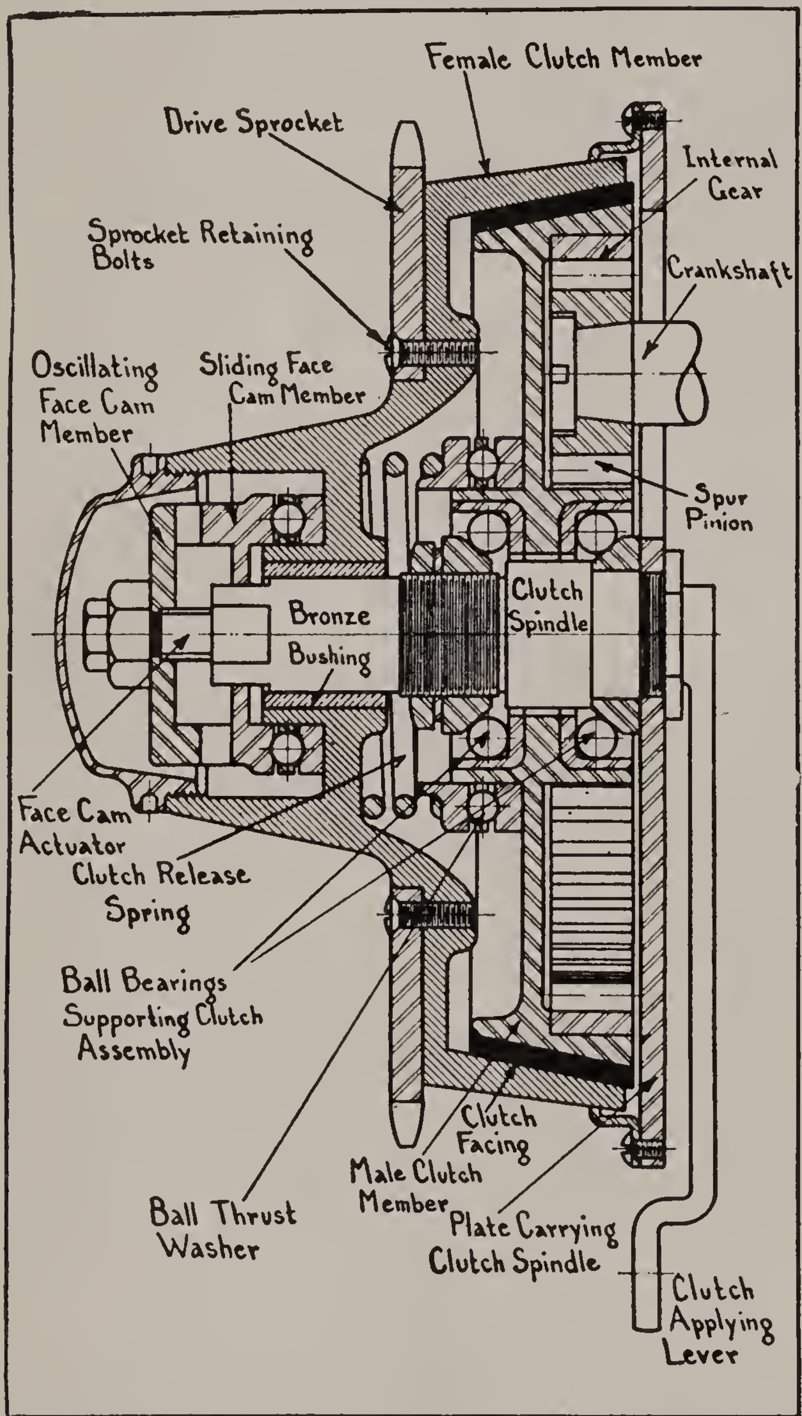


Fig. 163.—Sectional View of the Reading-Standard Cone Clutch.

The cone clutch used on the Reading-Standard motorcycle is outlined at Fig. 163. As all important parts are clearly depicted, the reader should have no difficulty in following the method of operation. In this clutch the spring is a releasing member and not an actuating member, as is true of the forms previously described. The clutch assembly is mounted on a spindle which is securely attached to a plate or anchorage member fastened to the engine base. The drive from the crankshaft to the male clutch member is through a spur pinion attached to the crankshaft which

meshes with a larger internal gear member that drives the male clutch casting. The female clutch member carries the drive sprocket that is connected to the rear wheel by a suitable chain, and in some models it drives a V-belt pulley.

Contrary to the usual cone clutch practice, the male clutch member does not move axially because it is held positively in place on the clutch spindle by two cup and cone bearings that prevent any endwise movement. To apply the clutch, the female clutch member is moved axially by a face cam arrangement. The oscillating face cam member, which has a series of inclined planes on its surface, is attached to a shaft that is moved by the clutch applying lever. A sliding face cam member that cannot rotate because it fits a squared portion of the clutch spindle is moved against the ball thrust bearing and presses the female clutch member firmly against the male clutch member as the pressure-applying lever oscillates the movable face cam member. When the clutch-applying lever is moved in a direction opposite to that necessary to apply the clutch, the face cam members separate and the clutch release spring pushes the female clutch member, which is movable, away from the male clutch member that is mounted on bearings that permit only a rotary movement. It is advanced by those who favor this form of clutch construction that much more gradual application is possible as the pressure is at the control of the rider than if obtained by means of the usual spring. It is claimed that should conditions demand it sufficient pressure may be exerted to lock the two portions of the clutch together into practically a single unit, whereas springs sometimes become weakened, and as the driving pressure is not positively maintained there is no way of remedying the slipping due to weakened springs except by replacing them or making a suitable adjustment of the pressure plate so the springs are compressed more tightly. The male clutch member is faced with frictional material in order to secure greater adhesion between the driven and driving members.

An example of a free engine clutch of the multiple disc type installed in the rear hub is shown at Fig. 164. This hub is used on Rex motorcycles which are of English manufacture. The driving member forms an inner hub that is independent of the outer hub shell except for the driving connection that exists when the discs are pressed

together. The flanged driving member B is attached to the driving pulley by suitable spokes and revolves on ball bearings P. The outer hub shell, which carries one set of discs is mounted on bearings N. When the clutch assembly K is pressed together by the springs J, the main hub A and the driving member B are securely locked together and ball bearings N do not revolve. When the internally threaded member E is moved on the externally threaded member or worm F,

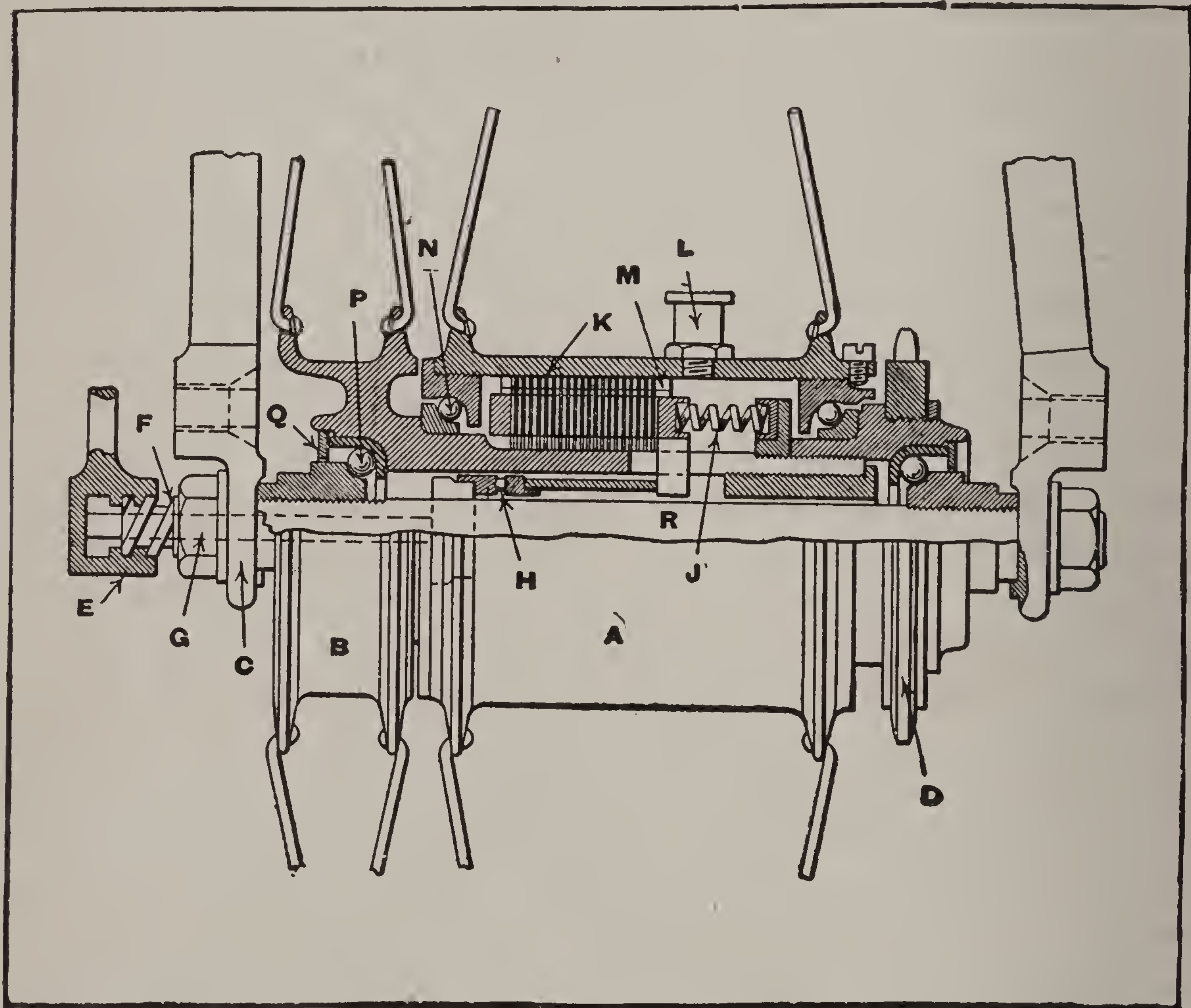


Fig. 164.—Detailing Construction of the Rex (English) Free Engine Clutch Forming Part of the Rear Hub.

it exerts pressure against the transfer rod G passing through one end of the axle R and pushes against a ball thrust bearing H which compresses the springs J by moving the pressure plate away from the disc assembly. When the discs are free, outer hub A can turn on ball bearings N independently of the member B, which continues to revolve as long as the engine is in motion.

Why Change Speed Gearing Is Desirable.—While the introduction of the friction clutch was a great step in advance, and made for rapid development of the motorcycle industry because it made it possible for people to operate motorcycles who would find it extremely difficult to manipulate the old directly connected types, still there is something lacking in a machine that is equipped only with a free engine clutch. We have previously considered the effect of the varying conditions upon the power needed to propel a motorcycle, and the writer has endeavored to make clear the relation the gear ratio must bear to the resistance. Under favorable conditions of operation,

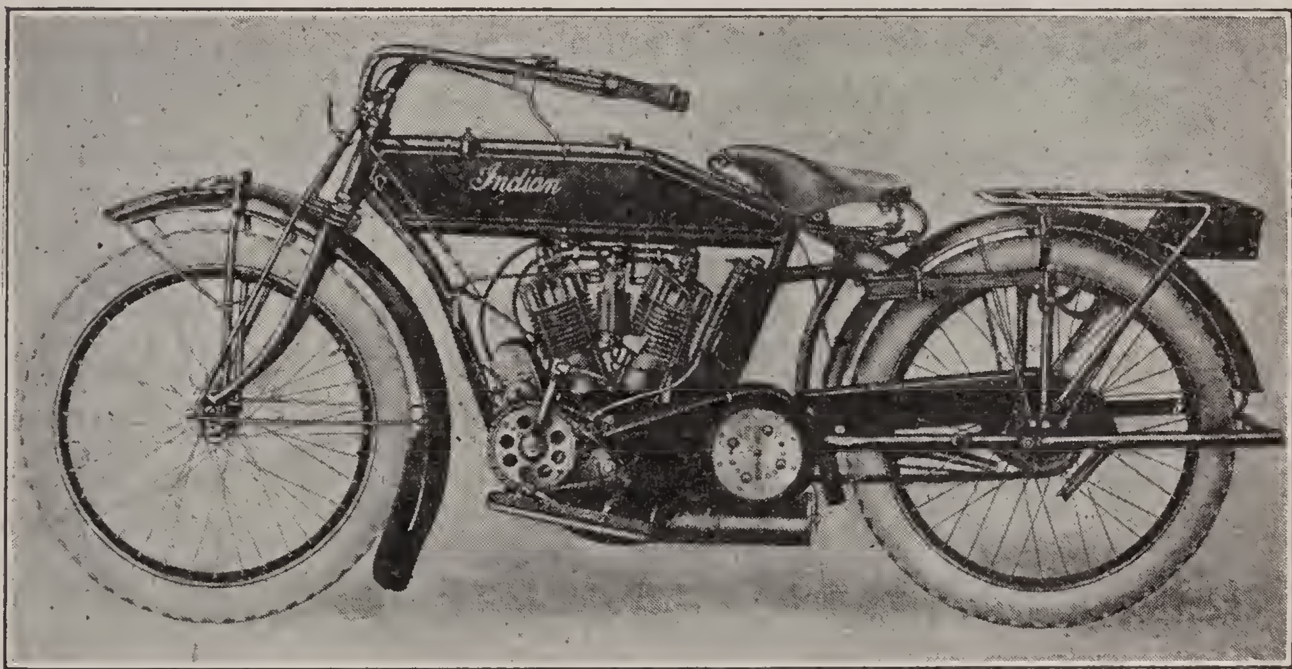


Fig. 165.—Indian Motorcycle With Two Speed Countershaft Gear.

when there is no undue influence to retard the progress of the machine, it is possible to drive the motorcycle without the expenditure of the entire energy the power plant is capable of. This makes high speeds possible and enables the engine to turn over at a number of revolutions that will permit it to exert the power necessary or even an actual surplus of energy. In a direct connected machine, as the resistance to motion increases, the tendency of the power plant is to slow down, which means that the power output is diminishing at a time that more is needed. If, therefore, some form of auxiliary gearing is provided that will permit the engine to run at its maximum speed and yet reduce the rear wheel and vehicle speed proportionate to the

resistance encountered, it will be possible for the engine to exert its full power at those times when the full capacity is needed, and, what is more important, the interposition of positive reduction gearing means that the power will be transmitted to the traction member where it can do useful work instead of being dissipated by heating the friction members of a slipping clutch.

Value of Variable Speed Gears.—If a two-speed or other variable gear did not permit of any other advantages besides enabling one to surmount gradients steeper than could be taken with a single-geared machine, this alone would justify its existence and make it profitable to install them in the modern motorcycles. When one considers that they permit of easy starting under any road condition or on any grade, and that they also make possible increased safety and superior control of the motorcycle in traffic, it will be understood why the general demand of the discriminating rider is for two-speed gears or equivalent devices.

A two-speed gear makes it possible to provide a smaller power plant without reducing the actual ability of the motorcycle in the least. It will climb any grade a single-geared motorcycle of greater capacity would surmount, and would be able to overcome many gradients and unfavorable road surfaces that the larger and more powerful machine could not be operated on. It provides positive control in traffic, a smooth running, and lack of vibration under all conditions that obviously could not be obtained with an engine having a larger piston displacement and proportionately greater force to the explosions. The small engine will also provide a satisfactory speed on the level, because on the direct drive or high gear the ratio may be sufficiently high to permit of high speed, owing to the provision of the reduction gearing to permit use of the lower ratio at such times as the resistance becomes too great to be overcome by the direct drive. The reduction of power plant capacity made possible by the two-speed gear will promote several other improvements in motorcycle design that will appeal to many of conservative temperament. The most important of these is undoubtedly the reduced cost, both in initial expense and maintenance of the lighter machine. If the power plant capacity can be reduced, then the weight of the motorcycle may be lessened, owing to the materially diminished stresses on the

frame, power transmission and supporting members. It costs less to drive a lighter machine, there is less depreciation and wear and tear if vibration is reduced. Smaller tires, less gasoline and oil consumption, greater comfort, and improved control are all desirable factors that will increase the pleasure of motorcycling, and augment the ranks of motorcyclists, and thus directly benefit the entire industry.

Variable Speed by Slipping Clutch.—Many motorcyclists are under the impression that the friction clutch in its various forms will permit of sufficient variation in the gear ratio to provide a margin of reserve power for hill climbing not obtained with a rigid drive machine. The free engine clutch is a very desirable improvement in motorcycles and has many advantages, inasmuch as it will permit the motorcycle to be started from a standstill, and enables the rider to stop his machine in traffic without stopping the power plant. It also provides for superior control in traffic, but is not an effective substitute for a variable speed gear of the positive type.

As any reduction in rear wheel speed, relative to that of the power plant, can only be obtained by slipping the clutch, it is obvious that the power lost in slippage between the friction surfaces can serve no useful purpose at the contact point of rear wheel and ground, and, in fact, if enough power is allowed to waste in this manner, sufficient heat may be generated by friction to seriously injure the mechanism comprising the clutch. As it is the rear wheel horse-power that counts in climbing hills or in pulling through sand, the variation in ratio between the engine shaft revolutions and rear wheel speed obtained by slipping the clutch does not increase the torque or pull at the rear wheel to any extent, and therefore is ineffective.

Consider a case where we have a motor capable of delivering 12 horse-power at 2,500 revolutions per minute. Almost any of our modern twin engines with a nominal rating of 8 to 10 horse-power can produce this energy. Assume that our gear ratio is 4 to 1, this means that with the clutch locked in positive engagement, that the rear wheel will be driven at 625 revolutions per minute, and that the rear wheel pull or effective power is equal to the capacity of the power plant minus the loss in transmission. If we assume 20 per cent. loss in transmission, we have an effective torque such as produced by 9.5

horse-power, and our rear wheel is revolving at 625 revolutions per minute.

Suppose we have a two-speed gear that will reduce the rear wheel speed to half that obtaining on the high or direct drive. If our engine runs at 2,500 revolutions per minute and our rear wheel turns at 312.5 revolutions per minute, we have practically the same effective torque as at the higher rear wheel speed, which obviously could not be used in climbing gradients because the increased resistance and the decrease in vehicle speed must be proportionate, if only the same amount of power is available at the motor. Of course, there would be a further loss due to the gearing, which would be compensated for by the lessened wind resistance due to the lower motorcycle speed. It will be evident that the introduction of a speed-reducing gear cannot increase the effective horse-power of the motor except that it permits the power plant to attain the same speed as with the higher ratio, whereas the motorcycle speed is reduced because the ratio of drive between rear wheel and engine is now actually 1 to 8.

Consider the result obtained by a slipping clutch in comparison with that secured by the interposition of intermediate speed-reduction gearing. The resistance to motion is such that the rear wheel cannot turn any faster than 312.5 revolutions per minute, and yet the horse-power required is just as great as though the rear wheel was turning at 625 revolutions per minute. The clutch is slipped sufficiently so the engine can run at its maximum speed of 2,500 revolutions per minute. The gear ratio between the clutch and rear wheel remains the same regardless of how much the clutch is slipped or 4 to 1.

Therefore, in order to get a rear wheel speed of 312.5 revolutions, the clutch-driven members must turn at 1,250 revolutions. The difference between that speed and that of the plates driven by the engine (assuming that the clutch is mounted on the engine shaft) is 1,250 revolutions per minute, which means that the clutch is slipping sufficiently to permit of the loss or actual waste of 50 per cent. of the power of the motor. The effective power output cannot be based on the number of engine revolutions but upon the revolutions per minute of the member driving the wheel. If the engine is delivering 12 horse-power to its crankshaft, but half that or 6 horse-power is being taken by the drive sprocket attached to the clutch member

turning at 1,250 revolutions per minute. The actual torque or horsepower available at the rear wheel must be based on the lower figure less the losses in transmission. Therefore, under conditions where the entire power capacity of the machine is needed to overcome resistance to motion, no form of slipping clutch can be effective because the diminution in rear wheel speed can only be obtained by wasting power represented by the revolutions of the engine lost in slip between the clutch members. At the other hand, the intermediate reduction gearing of the two-speed gear transmits power rather than losing it because it is positive and not flexible, and, while no gearing will work

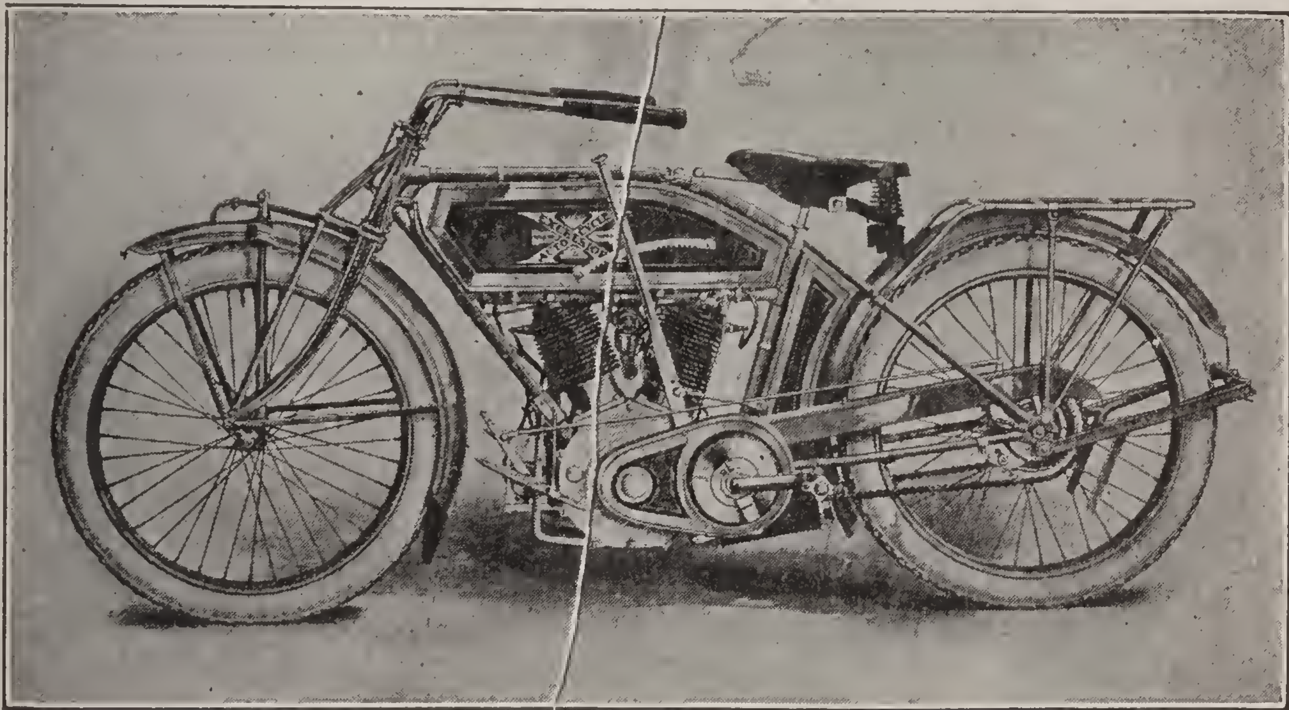


Fig. 166.—Showing the Location of the Planetary Two Speed Gear on the Excelsior Motorcycle.

without friction, the loss of energy through this added resistance is not to be compared with that wasted through clutch slip. While a friction clutch will provide variation of speed between rear wheel and engine shaft, it does this only at the expense of lost power, and a friction clutch is only effective for maximum power transmission when the clutch members are locked together and when clutch slipping is at a minimum. A reduction gearing reduces the speed without slip or loss other than that produced by the friction of gears and their bearings. It will be obvious that any claims where the friction clutch is given the same value as the reduction gear for obtaining varying

effective reduced speed ratios are absurd. The ideal combination is that of the reduction gearing and friction clutch, because with the two, we are able to obtain all the good features desired. We can slip the clutch on the level to slow up the machine, yet, when a hill or poor road confronts us, the reduction gearing may be brought in action to transmit power positively.

Change-Speed Gear Location.—As most forms of change-speed gearing are combined with a clutch, the usual method of location is the same as that which obtains with the friction clutches previously described. The simpler forms such as variable speed pulleys and some forms of planetary gearing are usually attached to the engine crankshaft. The most common location is at the crank-hanger where the change-speed gearing takes the place usually occupied by the simpler friction clutch. In some cases, the change-speed gear is incorporated as a unit with the power plant, though in most machines it is a separate mechanism distinct from the engine.

When change-speed gearing is employed, it is possible to dispense with the usual pedal starting gear, though it must be replaced by some equivalent device such as a kick starter or hand crank such as used on automobiles. The Indian motorcycle is made in one model "de luxe" with an electric self-starter very similar in action to those employed in automobiles. When the pedaling gear is eliminated, the control of the motorcycle is the same as that of an automobile, as the drive is interrupted by shifting a clutch instead of by raising the exhaust valves or interrupting the ignition as was formerly the practice with direct drive single-gear machines. The application of a kick starter to a modern two-speed motorcycle is clearly shown at Fig. 155, and in this construction the change-speed gearing replaces the usual crank-hanger. In the machine shown at Fig. 166, the variable speed gearing is used in connection with the pedal-starting lever, and is mounted as a countershaft, replacing the conventional friction clutch assembly widely used at that point.

In the Harley-Davidson motorcycle, shown at Fig. 167, the two-speed gearing is incorporated in the rear hub instead of being attached to either the crank-hanger or the engine shaft. The same reasons that are given for friction clutch location apply just as well as the two-speed gear, and the slower the parts turn the larger and more

substantial they must be to transmit the same amount of power. An engine shaft gear can have much smaller parts than a rear hub type, but, as is true of friction clutch design, a compromise between these two extremes is favored by most designers, and the speed gearing is installed at the crank-hanger in the form of countershaft where the speed of rotation is about half that of the engine shaft, and in some cases nearly twice as much as the rear wheel velocity.

Variable Speed Pulleys.—The simplest form of variable speed gear which involves the use of belt drive is the expanding V-pulley. A simple form in which the variation is obtained only when the pulley

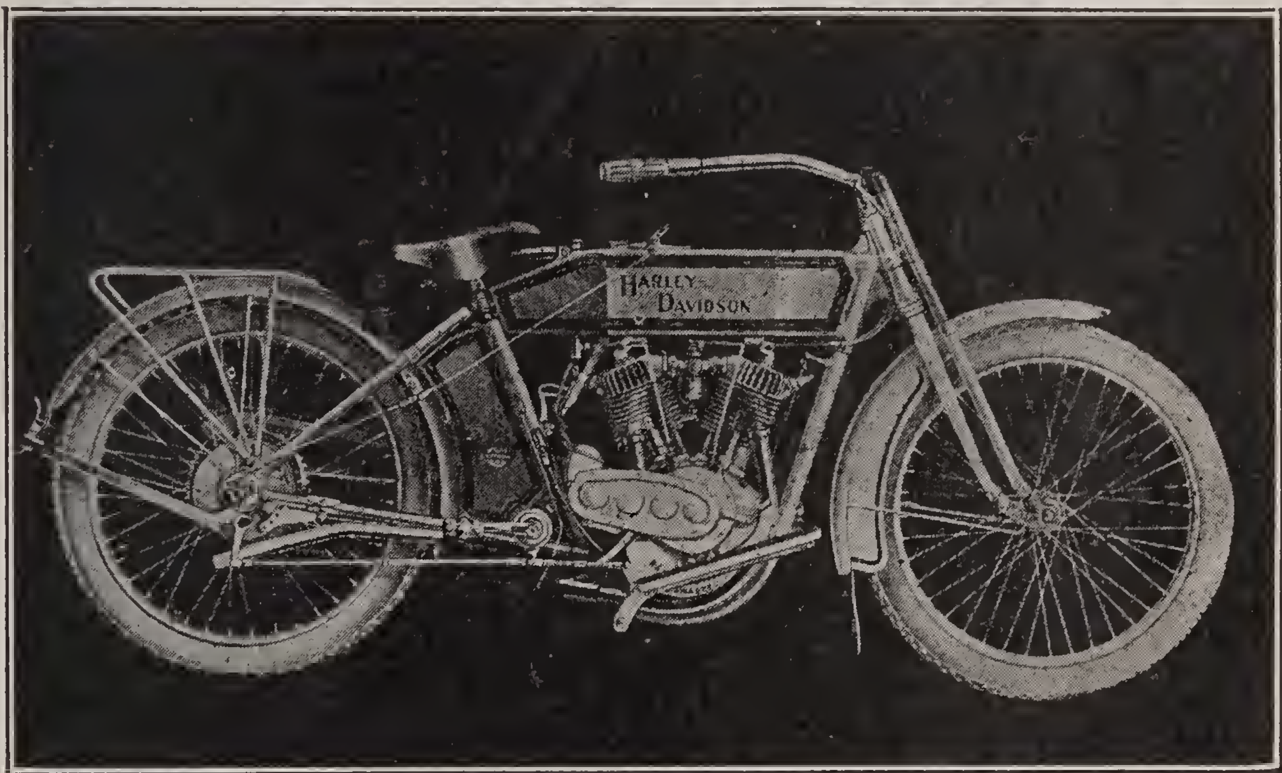


Fig. 167.—The Harley-Davidson Eight Horsepower Twin Cylinder Motorcycle, With Two Speed Gear in the Rear Hub.

is adjusted by the rider is shown at Fig. 168. In this, a fixed flange is attached to a hub that is provided with one large thread to receive the adjustable flange, and with a thread of smaller diameter to fit the locking member. The main portion is secured to the engine crankshaft. When the pulley is assembled, the nearer the flanges are together the higher the gear ratio, because the belt is forced to drive at the top of the flanges. As the flanges are spread apart, the belt can drop lower, and as it fits a portion of the pulley of lesser diameter, the ratio of drive will, of course, be lower than when it is at the top

of the pulley. The adjustment of the flange is a simple matter, as it involves merely the release of the locking member and the movement of the flange on its thread to the desired point. When the proper degree of adjustment has been secured, the locking member is set up tightly against the adjustable flange and maintained in position by it.

At Fig. 169, a pulley is shown that is said to compensate automatically for increased resistance at the driving wheel by providing a lower gear ratio. In this, the movable flange member is forced

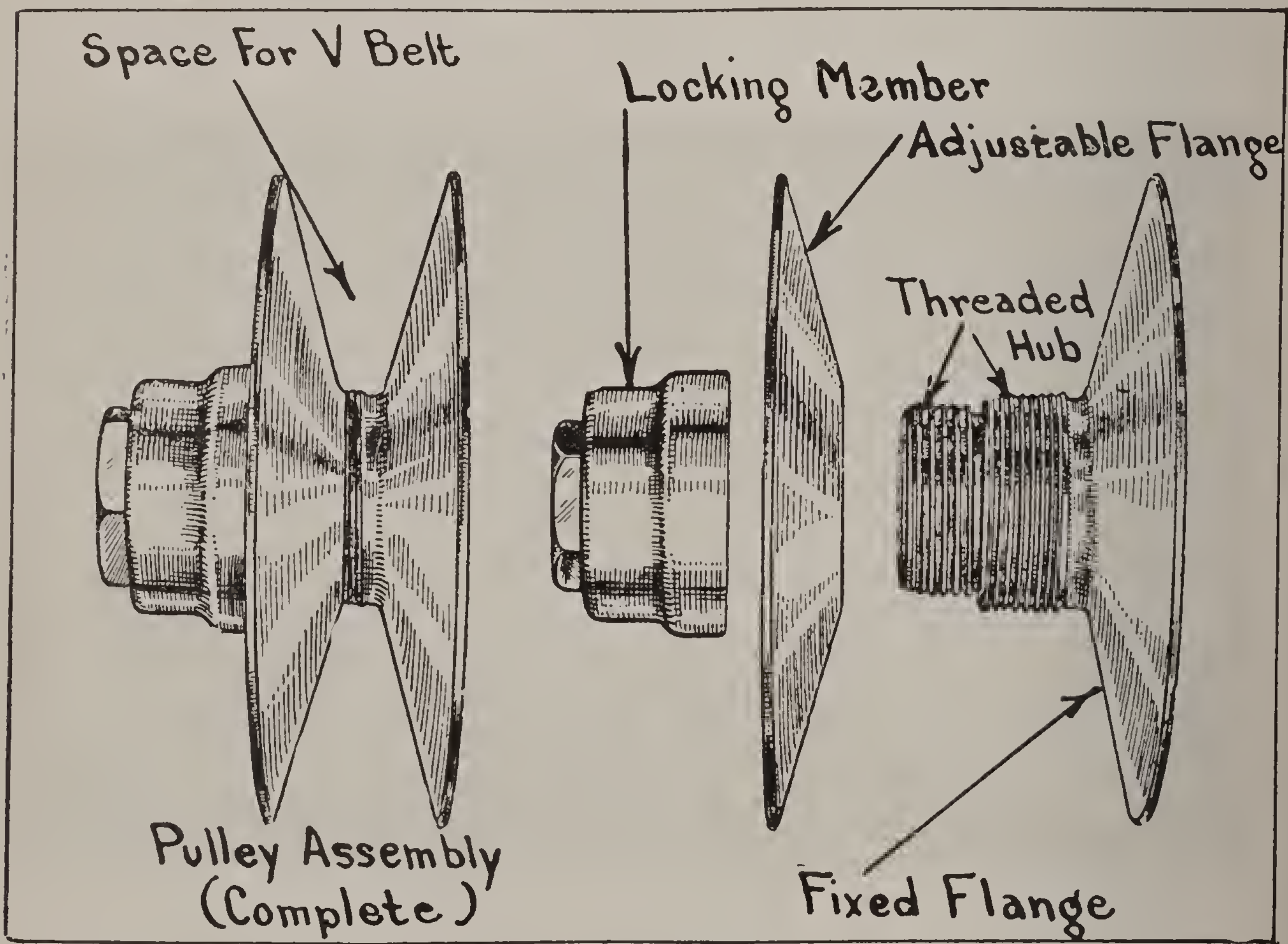


Fig. 168.—Construction of Simple Adjustable Pulley for V Belts.

toward the fixed flange by a series of coil springs, and it is claimed that as the resistance increases the belt tension becomes greater and forces the flanges apart until a point is reached where the ratio of drive has been reduced to the proper value. Variable pulleys of this form are provided with an auxiliary operating means which can be used to provide a lower gear ratio or a free engine independent of the resistance if desired.

The complete installation of the Auto-Varia, which is of English

design is shown at Fig. 170. A pulley control roll is mounted at the lower portion of a control handle, the upper end of which works in a sector attached to the frame. The function of the roll is to force the movable flange of the pulley outward when it is desired to obtain the lower ratio, and to spread the flanges so far apart that the belt

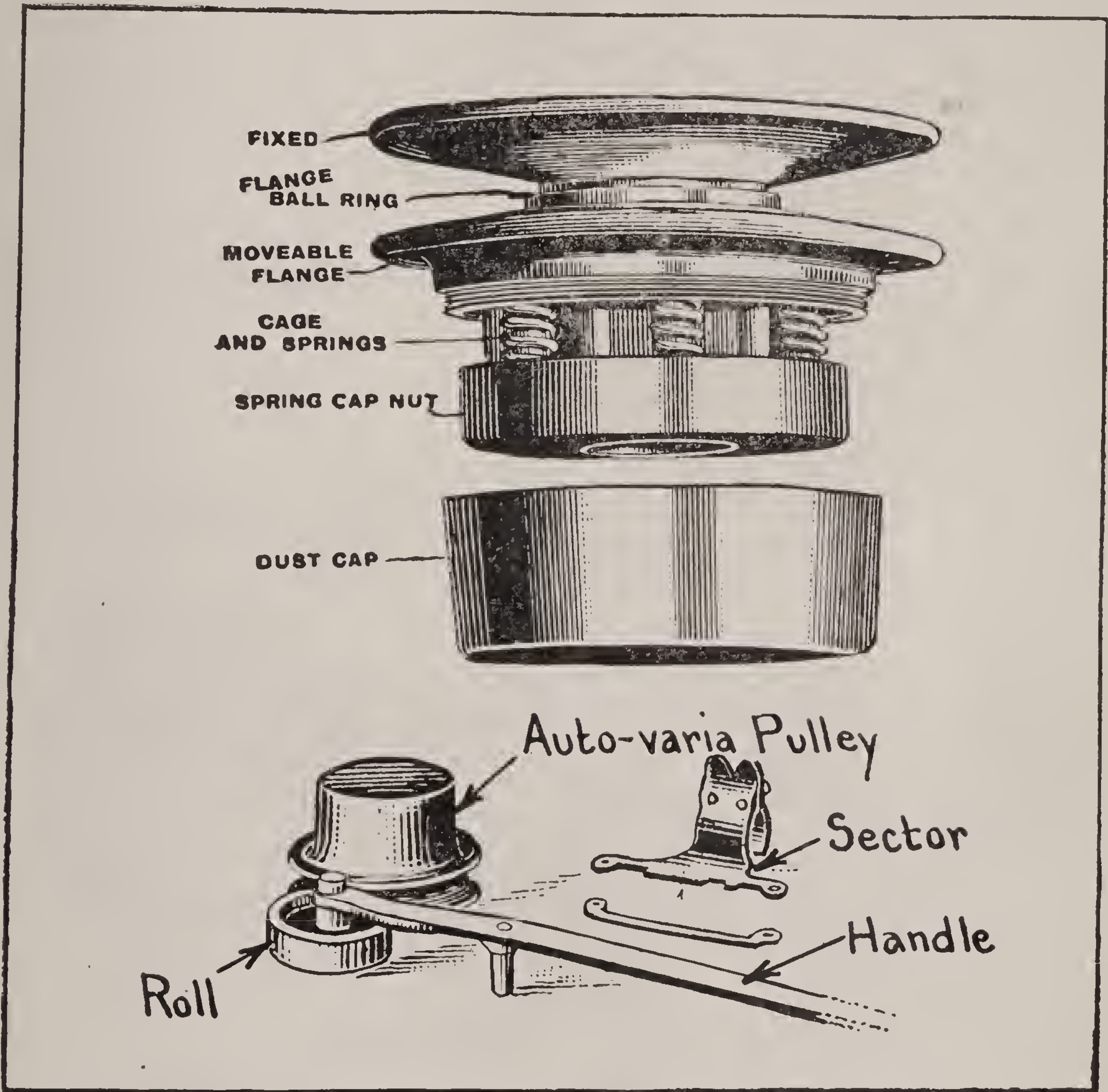


Fig. 169.—The Auto-Varia Pulley for V Belts.

will ride on a free, ball bearing supported ring at the bottom of the pulley when a free engine is desired. A variable pulley with which a friction clutch is included is shown at Fig. 171. This is a Rudge-Whitworth design and is said to give very satisfactory results. The action is the same as that of the simpler forms, means being provided for actuating the clutch that are independent of those available for

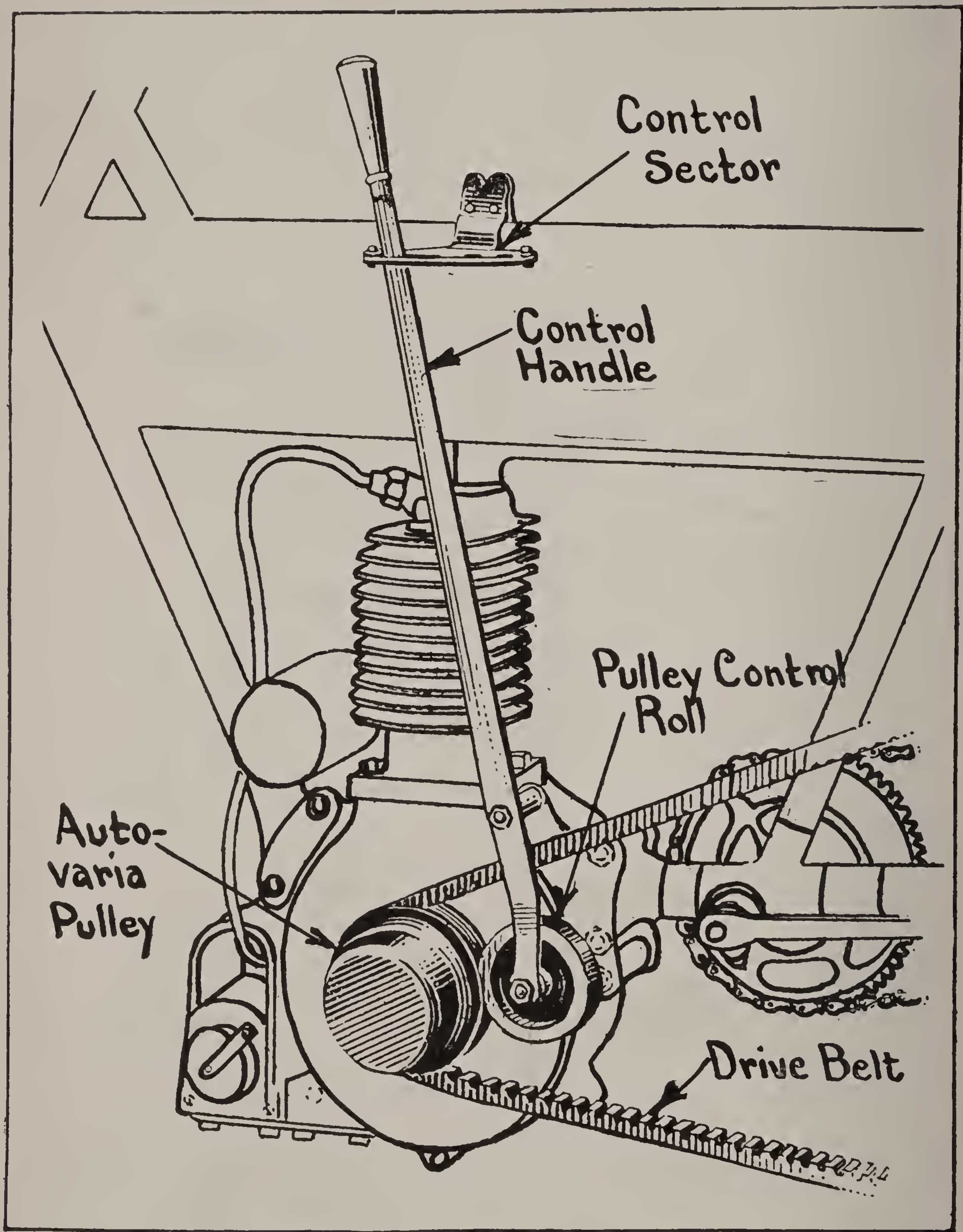


Fig. 170.—Showing Practical Application of the Auto-Varia Pulley and Control System.

varying the position of the movable pulley flange. With the driving belt in the position shown the flanges are spread apart as far as they will go, and the lowest ratio of drive is obtained. This device is rather

more complicated than some of the simpler forms that are said to give fully as good results in practice.

Engine Shaft Gear.—A two-speed and free engine planetary gear of English design, and sold under the trade name of "Fits all," is shown at Fig. 172. While the arrangement is such that the drive is by means of V-belt, it is possible to replace the belt pulley with a

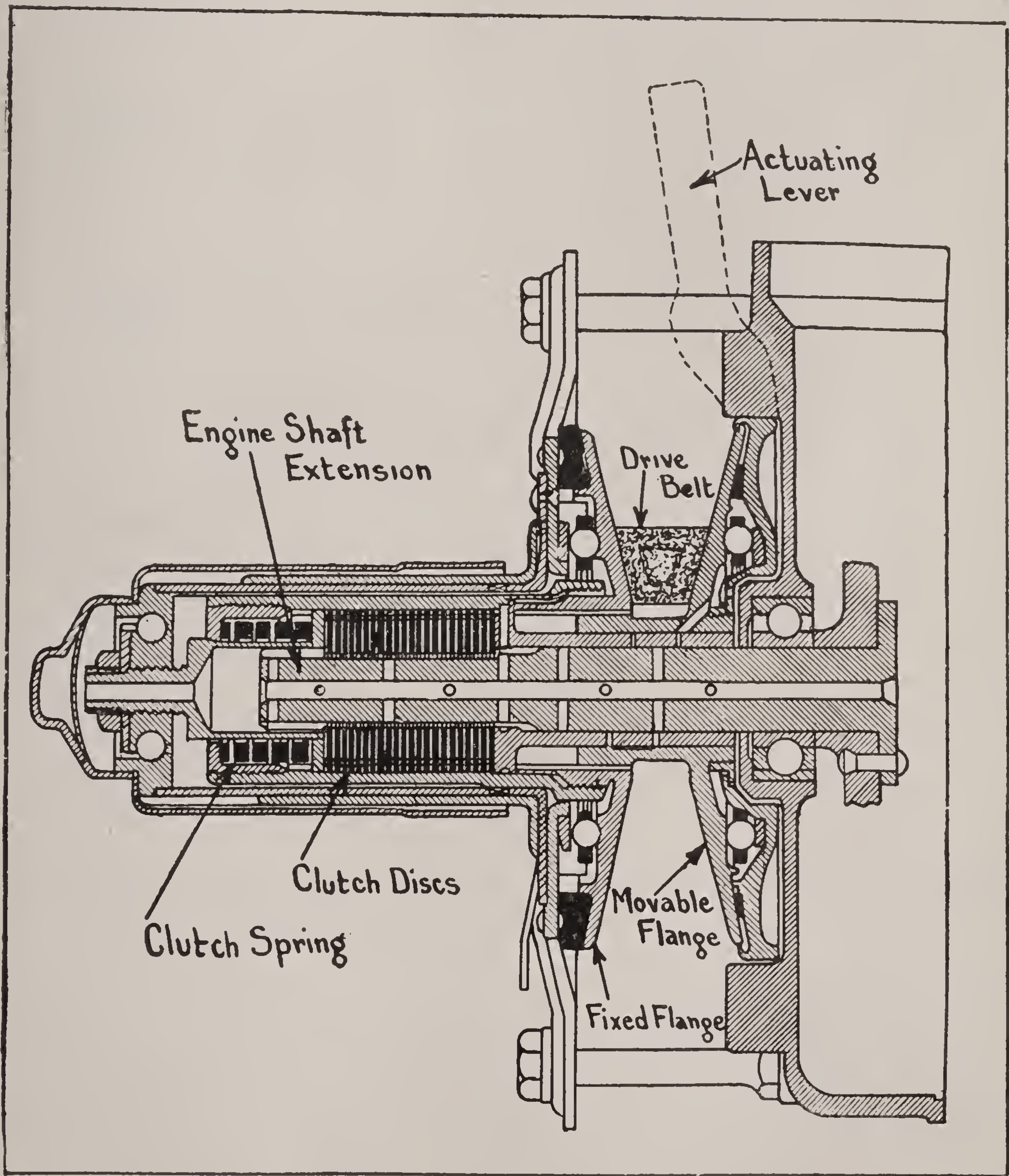


Fig. 171.—Variable Pulley and Free Engine Clutch Combination Used on the Rudge-Multi Motorcycle.

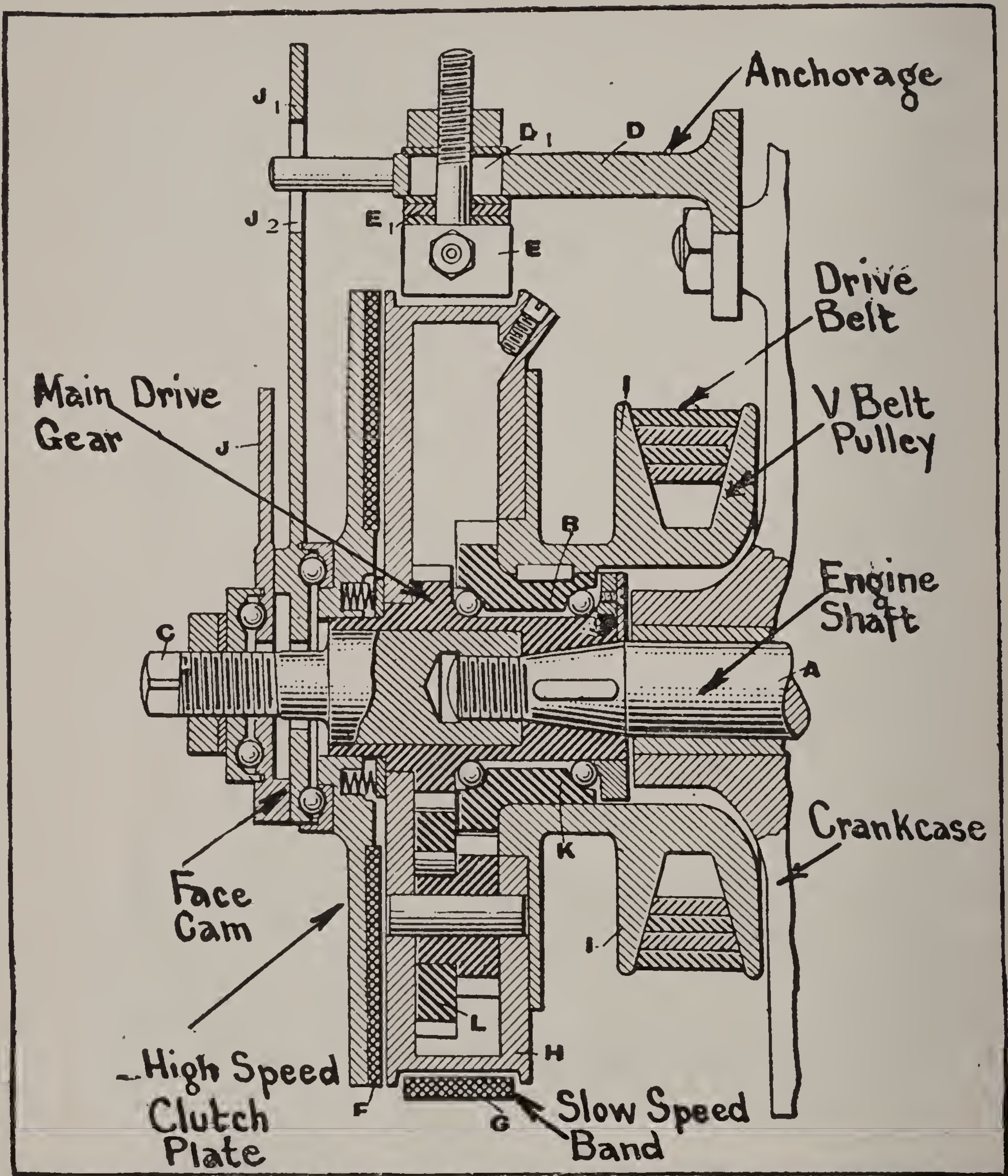


Fig. 172.—Sectional View of Typical Planetary Two Speed Gear, Adapted for Application to Engine Shaft.

sprocket, and obtain chain drive. The action of this gear is simple, and, if thoroughly understood, it will serve to make clear the principles underlying speed reduction by all forms of planetary gear sets. A main driving member that carries the assembly is securely keyed to the engine shaft A and is held firmly in place by a threaded shaft extension that forms an auxiliary support for the gear assembly. When the parts are in the position shown in the sketch, the engine

may turn without driving the rear wheel because the main driving gear will rotate the planetary reduction gears L around on the bearing stud on which they rotate without producing any movement of the pulley I. If the friction band G is clamped around the drum H to keep it from turning, while the planetary pinion assembly L will turn on the stud, the pinion carrier H cannot rotate and the planetary pinions therefore serve as an intermediate gearing connecting the main drive gear with the pulley drive gear B. The main drive gear is about the same size as the larger gear of the planetary pinion assembly and therefore turns it at about the same speed. The small gear of the planetary pinion assembly is smaller than the driving gear B with which it meshes so a reduction in speed is possible between the belt pulley I and the engine shaft A due to the difference in size between gears B and the small member of the assembly L. While but one spur pinion assembly is shown, most planetary gears use two or more sets spaced equally around the casing H in order to equalize the driving strain and prevent wear on the bearings that would be unavoidable if but one set of intermediate pinions was employed. When it is desired to obtain the direct drive, the brake band G is released and the high speed clutch plate F is firmly pressed against the side of the drum H by a face cam and ball thrust arrangement, controlled by the rider, and the entire assembly is thus locked together as a unit so the drive is direct from engine shaft A to the drive pulley I.

Countershaft Gears.—Countershaft gears are made in infinite variety, and they may form part of the power plant unit or be attached to the crank-hanger. The views of the De-Luxe motor at Figs. 173 and 174 show clearly the external appearance of a two-speed gear of the countershaft type when it forms part of the power plant. This makes it possible to utilize the regular pedal-starting gear, if desirable, as the change-speed gearing is placed forward of the crank-hanger and is independent of it. Where the change-speed gearing is not a part of the engine case and must be supported from the crank-hanger, it is sometimes impossible to utilize the pedal gear for starting the engine, so an auxiliary starting-crank arrangement, such as shown at Fig. 175, must be used to turn the engine crankshaft over and start the motor.

The arrangement may be easily understood from the illustration.

The view at A shows the starting crank in place with the jaw clutch making a suitable connection between the starting-handle shaft and the main gear shaft, as soon as the engine starts the handle is automatically released, and a coil spring will force the starting clutch out of engagement so that the member to which the starting crank is attached does not rotate except when it is pressed into engagement with the clutch member by suitable end pressure on the starting handle.

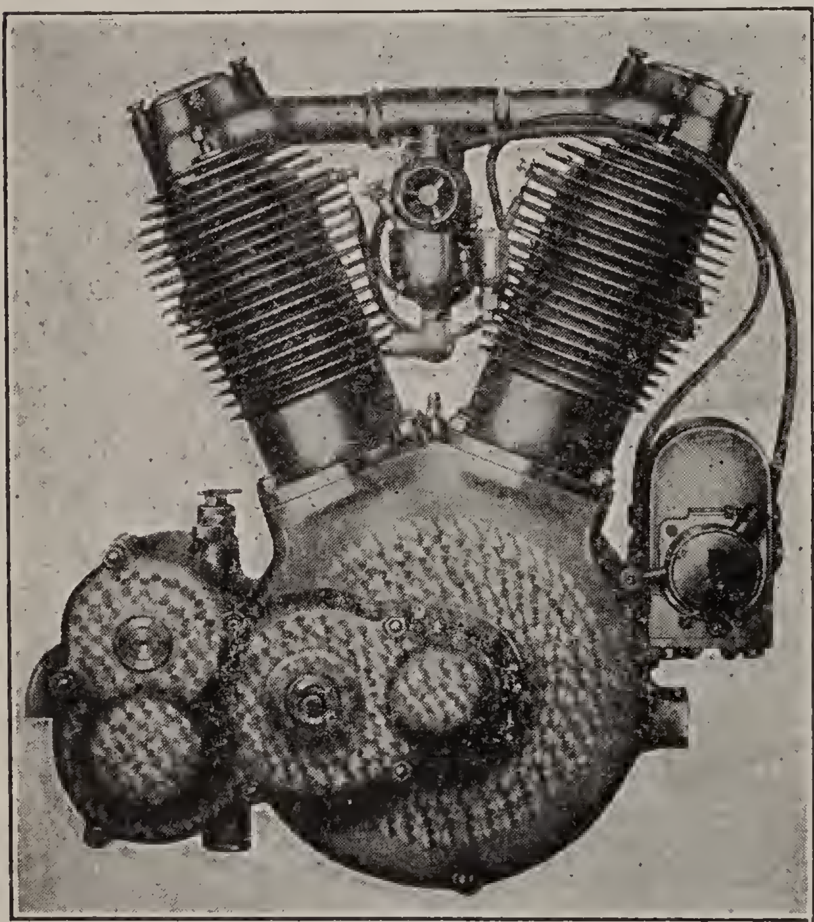


Fig. 173.—Carburetor Side of Spacke Two Cylinder Motor With Two Speed Gear Integral With Power Plant.

The arrangement of the clutch and change-speed gearing in the Michaelson unit power plant is outlined at Fig. 176. In this, the multiple disc clutch of the usual pattern is attached to an extension of the engine crankshaft, and drives an intermediate gear assembly consisting of two gears, one larger than the other, which in turn transmit the crankshaft motion to a suitable spur gear on the main driving shaft of the two-speed gearing. The arrangement of the gears in this variable speed member is practically the same as those shown at Fig. 179. A shifting clutch member clutches either of the gears to the sprocket-drive shaft. The use of the intermediate gear member provides for a first-speed reduction gear completely enclosed and running in oil. This power-transmitting element takes the place of the usual short chain that joins the engine crankshaft to the conventional countershaft gear arrangement such as outlined at Fig. 178. The engine is started by a small sprocket member that drives a suitably

formed clutching member at one side of the gear case and which engages the main shaft of the change-speed gearing. This position is preferable to a direct application to the engine crankshaft because the engine is started through the intermediate gears, which insures that the crankshaft B can be maintained at a higher rate than would be possible by direct application of the starting handle, owing to the geared-up drive between the starting means and the crankshaft. In order to start the average motorcycle power plant promptly, it is necessary to rotate it at a fairly high rate of speed. This was always an important advantage in connection with the usual pedal-starting gear, because the rear wheel could be turned over fast enough by the feet to revolve the engine crankshaft at a higher rate of speed than is possible with most kick starters or equivalent devices. There are conditions where it is important to turn the engine over fast to secure prompt starting, such as in cold weather when the gasoline does not vaporize readily. The application of the geared-up starting crank gives practically the same rotative speed as would be obtained through the conventional pedal-gear arrangement.

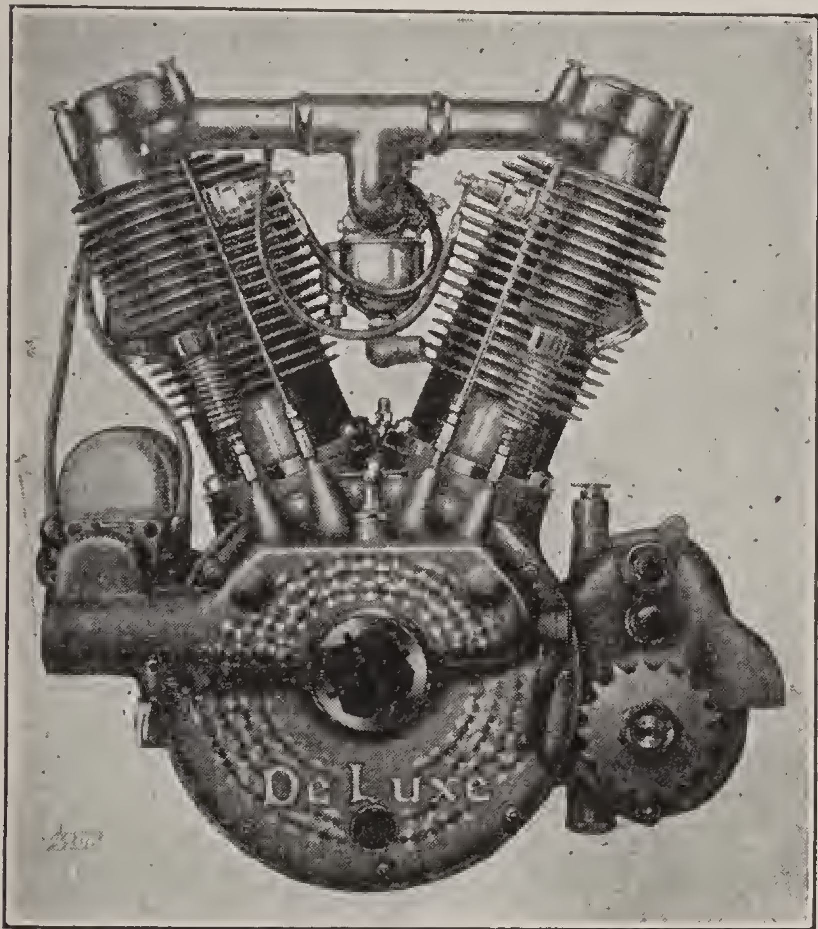


Fig. 174.—Valve Side of De Luxe Unit Power Plant Showing Driving Sprocket on the Gear Box.

The Minneapolis power plant which is shown at Fig. 177 is similar in general arrangement to the Michaelson, but employs a distinctive means of speed changing. The transmission is of the planetary type using positive clutches for both high and low speed which, of course,

is made possible by utilizing a master clutch on the engine crankshaft. A jaw clutch member is adapted to slide on a bushing surrounding the main shaft, and this may be engaged either with the member carrying the planetary reduction or it can be moved over to push a clutch member in engagement with the driving gear of the transmission shaft. When in the position indicated, the gear that drives the transmission shaft is clutched to that member. If the jaw clutch is moved to the other extreme, a series of projections extending from

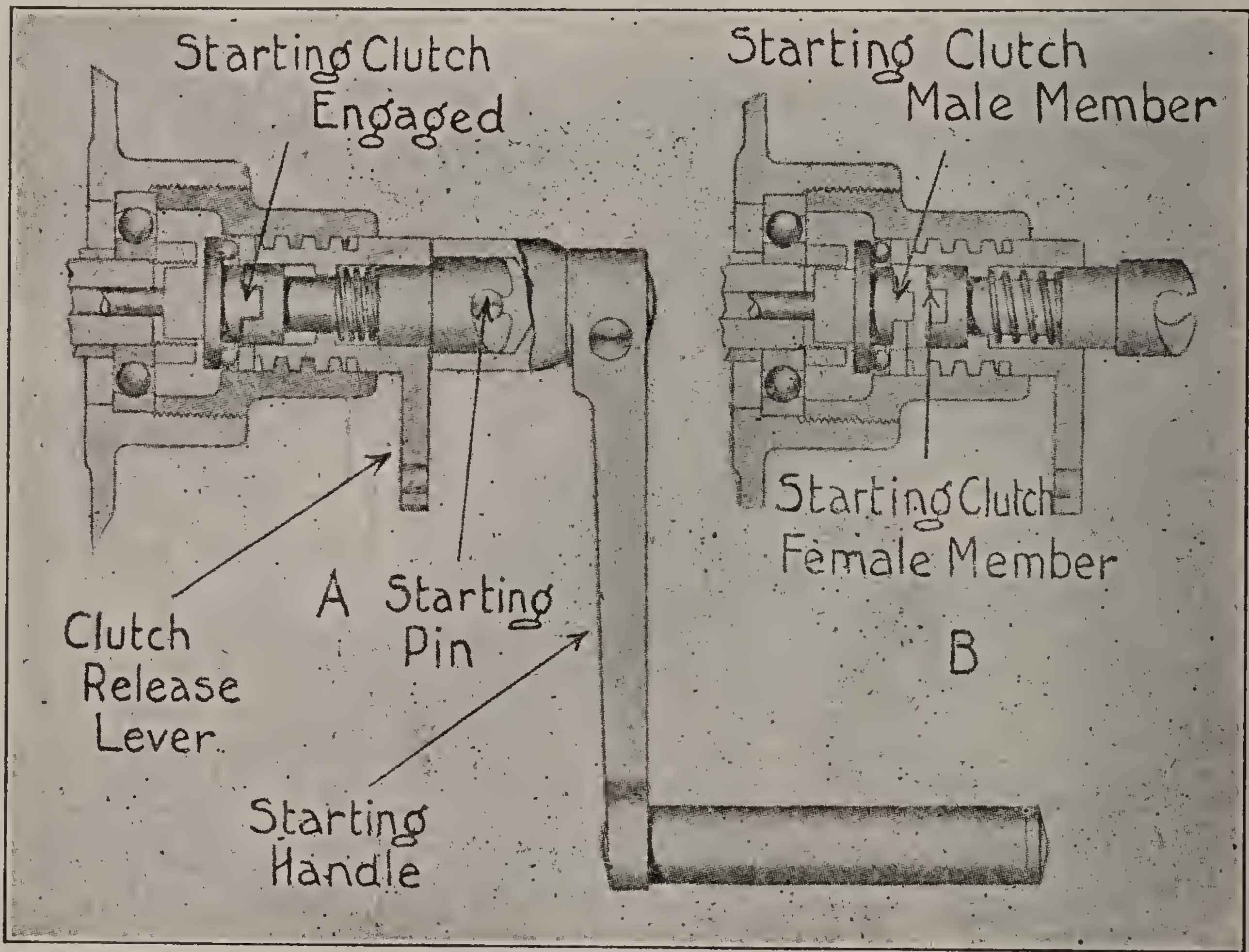


Fig. 175.—Starting Handle Clutch Arrangement Used in Connection With Jardine Two Speed Gears.

the face of the clutch shifter engage suitable depressions in the planetary gear-carrying plate, and keep that member from rotating because the jaw clutch shifter is securely anchored to a through bolt, extending from one side of the gear case to the other, which keeps it from rotation. When used in connection with planetary gearing, it takes the place of the usual band clutch, and the drive is then to the member carrying the driven spur gear inside of the case, and threaded

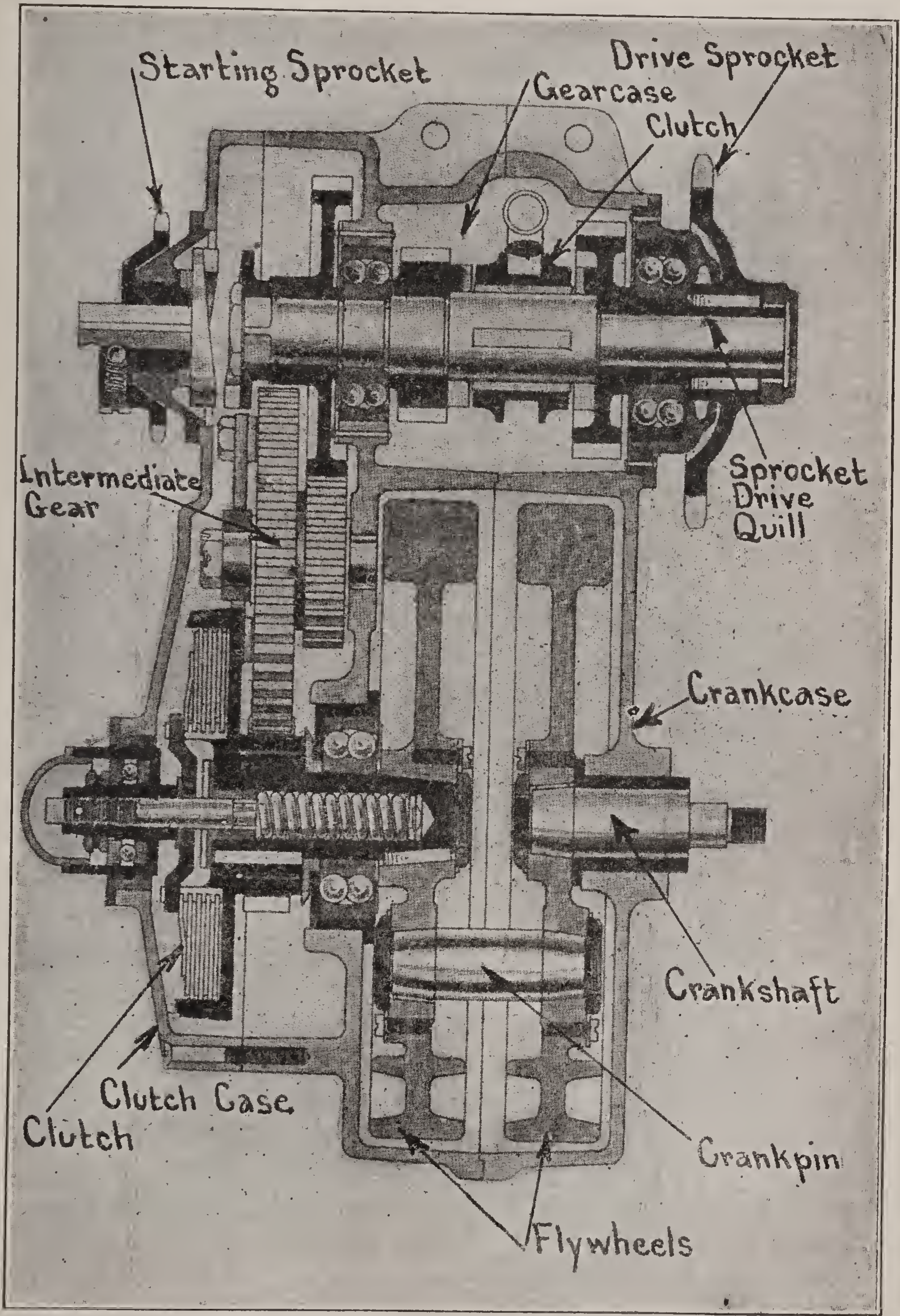


Fig. 176.—Showing Arrangement of Change Speed Gearing in Michaelson Unit Power Plant.

on the outside to receive the driving sprocket. With this construction, it is imperative that the master clutch be released before either the high or low speed is engaged.

The usual installation of a countershaft gear of the shifting jaw clutch type is shown at Fig. 178. At the bottom or plan view, the relation of the gear to the engine base, and the method of driving from the engine crankshaft, is clearly shown. A compensating clutch at the engine crankshaft is utilized to prevent depreciation of the chain through unsteady power application and from the sprocket mounted on that member, the drive is by chain to the sprocket attached to the main clutch member that forms part of the countershaft gear. The drive to the rear wheel is from the smaller sprocket on the countershaft to a suitable member on the rear hub. The method of shifting the speed is also depicted, the jaw clutch controlling the two speeds is operated from a small lever attached to the top frame tube which works on a notched quadrant providing three stops for the lever. The center one is in neutral position, and at such times as the small lever stands vertically, the shifting clutch in the transmission interior is at a point between the two engaged positions. Moving the lever to one extreme or the other will engage the high or low speed respectively. The clutch is shifted by a foot pedal attached to the bottom of the bracket supporting the power plant.

The interior arrangement of the Indian two-speed gear, which is representative and the original of all the shifting clutch forms, is shown at Fig. 179. A friction clutch of the regulation Indian pattern serves as a master clutch, and the drive from the engine is directly to a large driven sprocket attached to the clutch casing. A driven shaft passes through the center of a hollow quill or bushing, at one end of which the drive sprocket that transmits the power to the rear wheels is secured, while at the inside a spur gear is mounted. The jaw clutch is keyed to this shaft which is supported at its other end by a ball bearing. This shaft is also hollow, and the clutch release rod passes through the center of it. The jaw clutch member is adapted to be shifted from its central position to either the right or left to engage suitable teeth projecting from the face of the two gears. The gear that is attached to the bushing carrying the sprocket meshes with a smaller member carried on a countershaft to one side of the

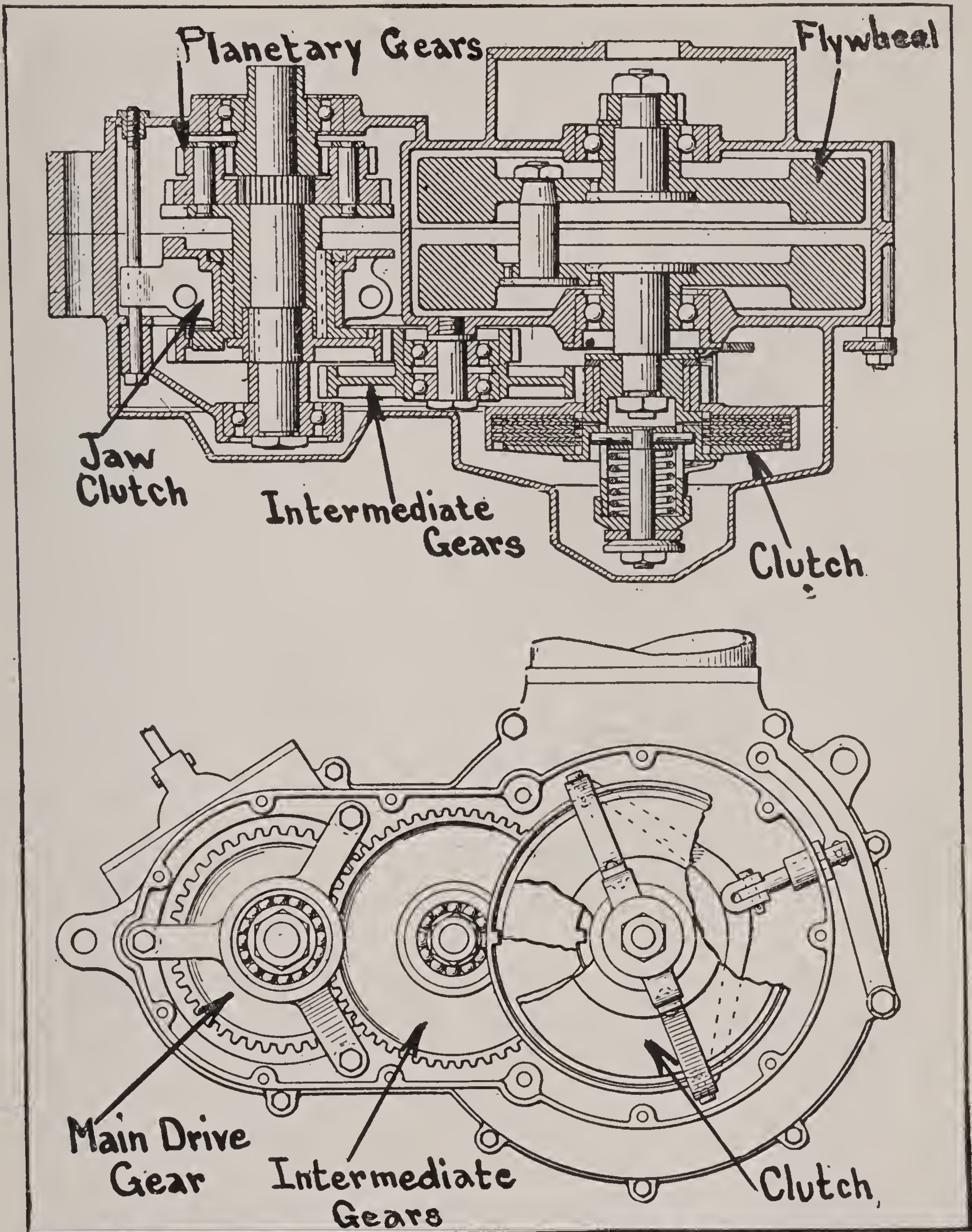


Fig. 177.—Views Depicting Construction of the Minneapolis Unit Power Plant and Gearset.

main shaft. A larger gear on the countershaft meshes with a smaller member that is normally free to revolve on the main shaft, and which is independent of it at all times except when the jaw clutch is moved over to engage with the teeth on its face.

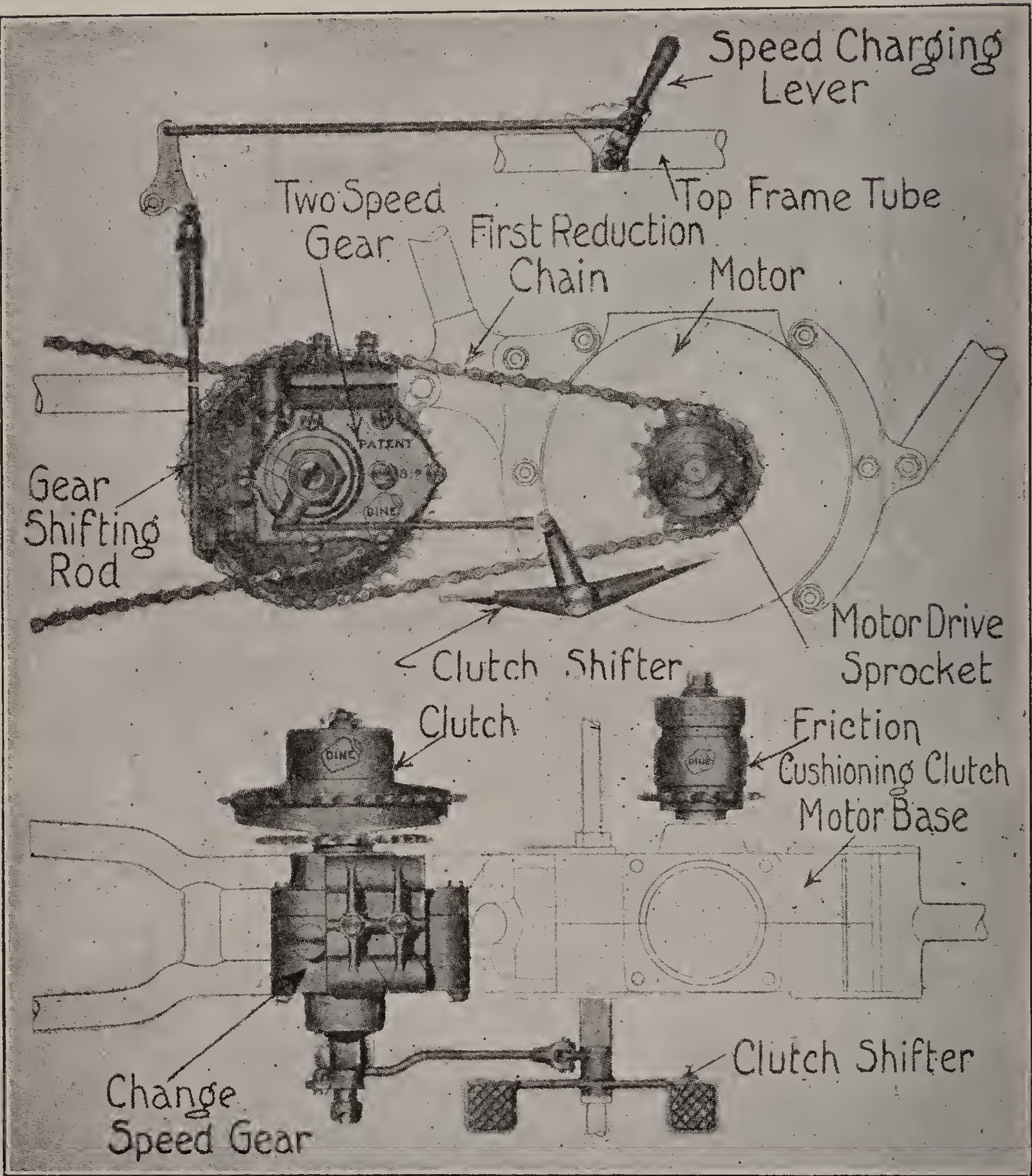


Fig. 178.—Methods of Installing the Jardine (English) Countershaft Type Two Speed Gear.

With the jaw clutch in the position shown, even if the master clutch is engaged, the rear wheel will not turn because the sleeve carrying the drive sprocket does not rotate. To obtain the low speed ratio, the jaw clutch is moved to the right to make fast to the shaft the smaller of the gears mounted on that member. The drive is then from the clutch to the small gear, which, in turn, drives the large gear on the countershaft at a lower rate of speed. The other gear

member on the countershaft is smaller than the sprocket drive gear, and a further reduction of speed is possible between these two. The driving sprocket is turning in the same direction as the main shaft, but at a lower rate of speed on account of the reduction gears interposed between the sprocket and the clutch-driven shaft. To obtain the high-speed ratio, the jaw clutch is moved to the left, and makes the sprocket-drive gear fast to the main shaft. This means that the driving sprocket would turn at the same speed as the main shaft to which the clutch is attached. The master clutch is shifted by a

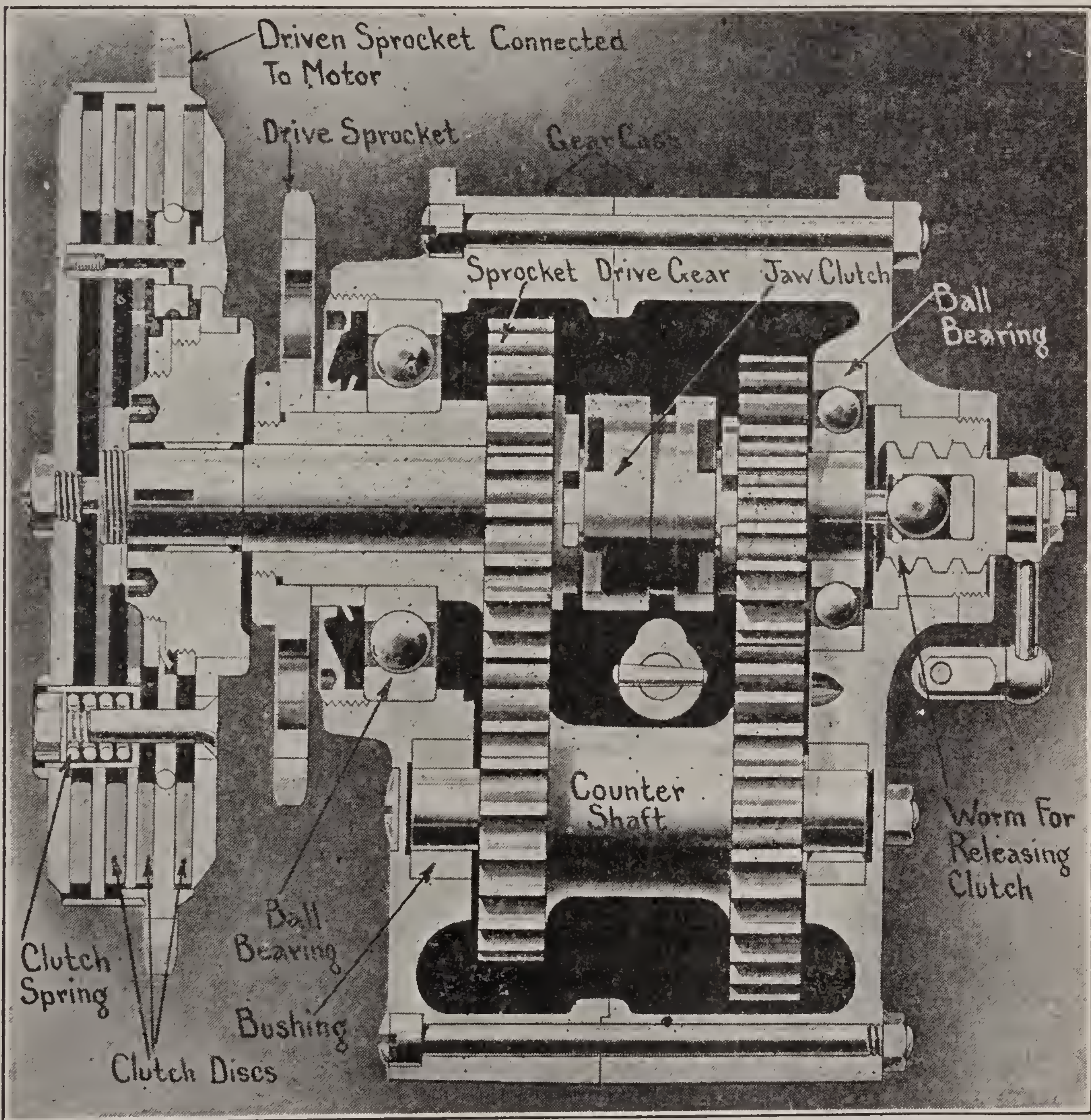


Fig. 179.—Sectional View Showing the Two Speed Individual Clutch Gear and Master Clutch of the Friction Type Employed on the Indian Motorcycle.

releasing worm that exerts pressure against a rod passing through the center of the main shaft, and attached to the outermost clutch plate. When this plate is moved to the left, the clutch springs are compressed, and the driving pressure between the plates is interrupted. It is necessary to release the master clutch at all times that the jaw clutch member is shifted, because if the positive clutch is moved with the friction clutch engaged it will start the motorcycle so suddenly that the parts of the transmission system may be stressed to the breaking point.

Another form of countershaft variable speed gear is shown at Fig. 180. This differs from the type previously described, in that it is a sliding gear form and provides three forward speeds instead of two as is common practice. The power from the engine is delivered to the clutch case by the sprocket A, and the inner member of the clutch is attached to and drives the main shaft B of the transmission. A sliding gear D is mounted on the main shaft, and is provided with clutch projections E on both sides. When the member D is moved to the extreme right of the gear case, the projecting teeth E clutch corresponding members on the small spur gear G, thus locking the gear G to the main shaft. The gear G is considerably smaller than the gear L mounted on the countershaft H, and turns that member at a lower rate of speed. The driving sprocket M is attached to a bushing to which the sprocket-driving gear is securely fastened. The constant mesh gear on the countershaft H that meshes with the gear F is smaller than that member, and thus a further reduction in speed is obtained. The driving sprocket M turns at a considerably lower speed than the main driving shaft B, owing to the two reductions obtained, one between the gears G and L, and the other between the small constant mesh gear on the countershaft and the sprocket gear F. If the sliding member B is engaged with the member K on the countershaft there is but one reduction in speed, and that is between the constant mesh gears, because the gears D and K are practically the same size. This is an intermediate ratio that is not as slow as the low speed, and yet is slower than the direct drive.

If the sliding member D is moved to the extreme left, the clutch teeth E-1 will engage suitable members projecting from the gear F, and will lock the sprocket drive gear directly to the main shaft and

obtain a direct drive. With this form of transmission, it is even more important to release the master clutch before speed changes are effected than it is with the sliding clutch forms in which the gear teeth are always in mesh. If the sliding member D is moved into mesh with the gear K, with the clutch engaged, it will be apt to produce serious damage to the teeth of the two gears, because it is almost impossible to mesh spur gears when both are in motion. A kick starting

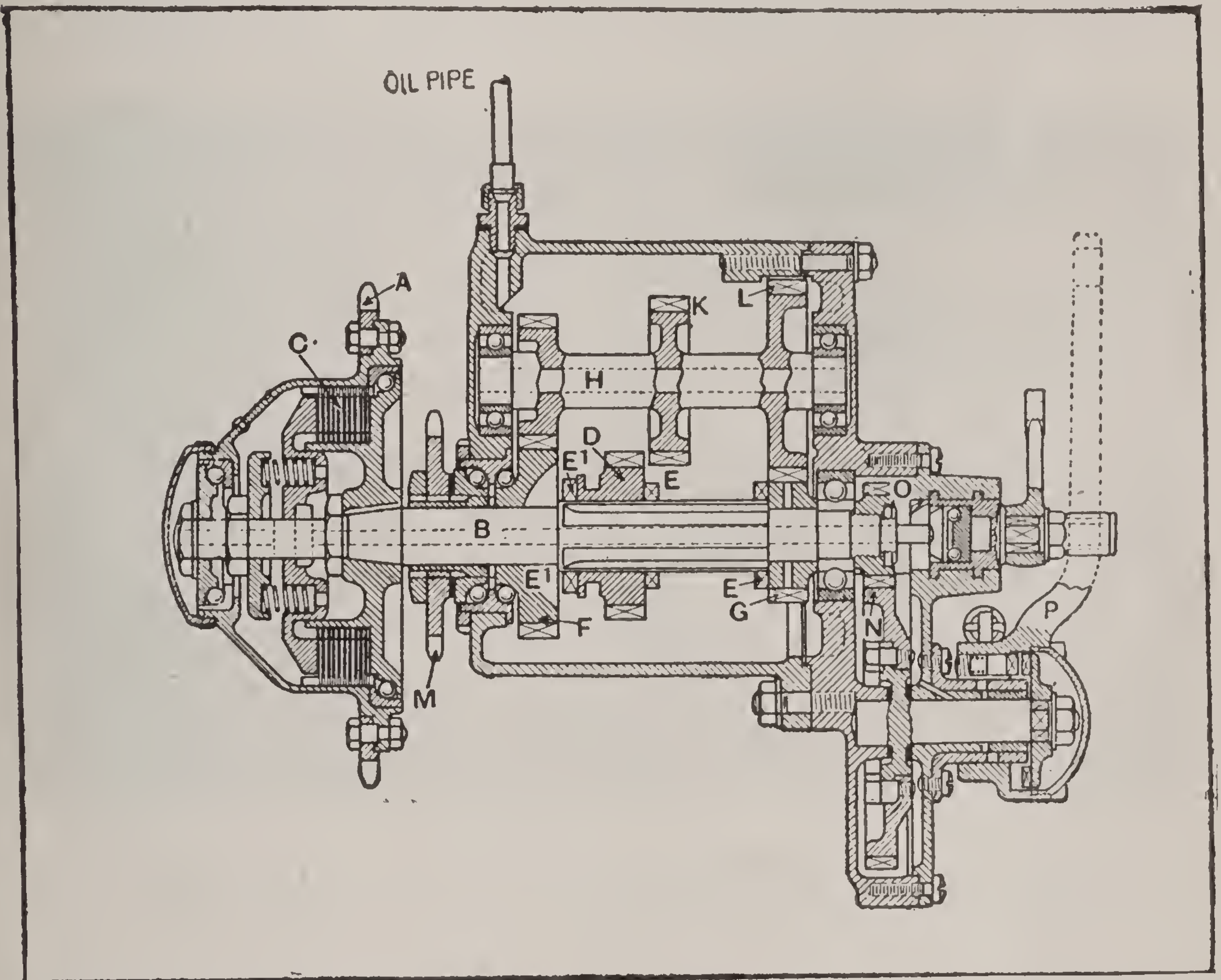


Fig. 180.—English Three Speed Countershaft Change Speed Gearing of the Sliding Type.

gear is incorporated with this gear-set. The pedal crank P which is adapted to be pushed by the foot of the rider is clutched to the gear N which meshes with a much smaller gear O attached to the main shaft B. Even if the pedal P is only moved through a small portion of a revolution, the engine shaft will be turned several times on account of the gearing of the starter as well as the step-up between the large sprocket A on the clutch and the smaller member on the engine shaft.

Rear Hub Gears.—Several forms of rear hub gears have been applied, and these are practically all of the planetary type. That shown at Fig. 181*a*, in cross section, and at Fig. 182, in partial disassembly, is used on the Thiem motorcycle, which is an American design. The gear itself is patterned very closely after a popular English two-speed hub. The method of obtaining the low speed by the use of planetary reduction gears is practically the same as that employed in the engine shaft gear shown at Fig. 172. A suitable brake band clutches a drum securely fastened to the axle, and one

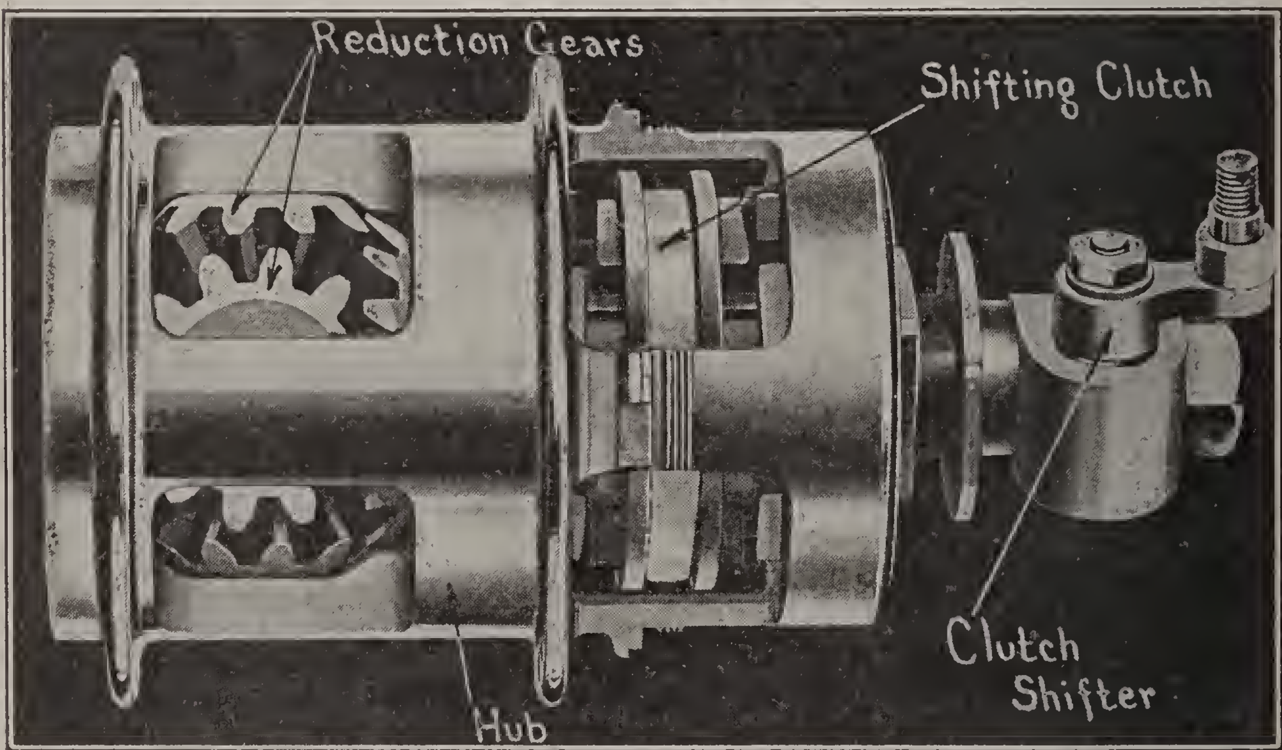


Fig. 181.—Novel Method of Speed Reduction by Bevel Gearing Incorporated in the Harley-Davidson Two Speed Hub.

of the main gears of the planetary reduction is also keyed to the axle. The other sun gear, as the central main member is called, is attached to the hub member proper. The drive from the motor is by V-belt to a pulley rim laced to the drum carrying the planetary reduction gears by the conventional wire spokes. When it is desired to apply the low speed, the brake band that works on the outer drum is constricted and holds that drum and the axle to which it is fastened stationary. The planetary pinions are free to revolve on their retaining studs and drive the hub shell because they must turn it in the same direction, though at a slower rate of speed, than the pulley rim

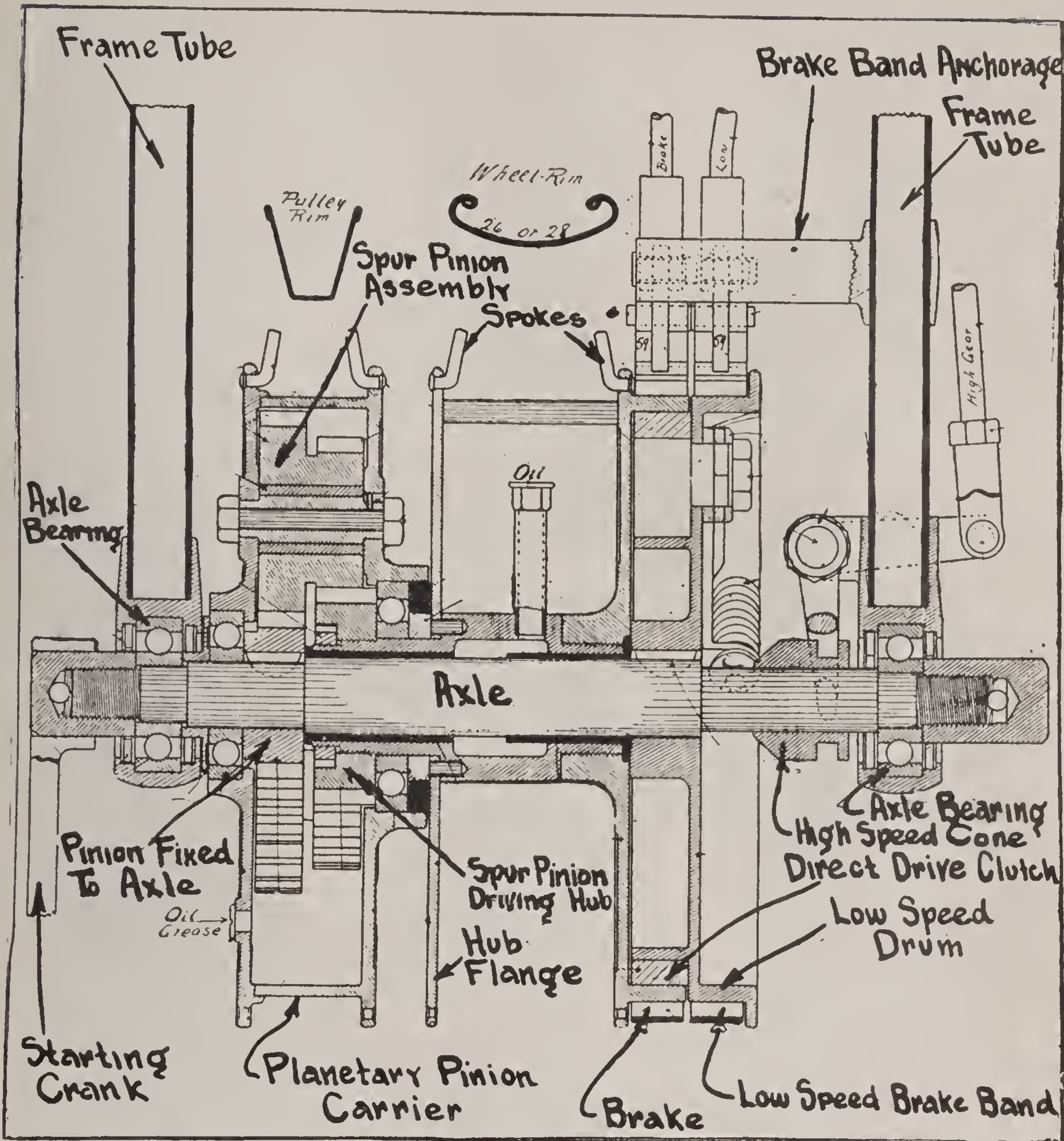


Fig 181a.—Sectional View of the Thiem Two Speed Rear Hub.

travels on account of being forced to roll around the spur gear keyed to the axle. To obtain a high speed, an expanding band clutch is engaged by leverage actuated by a shifting cone, and the entire hub assembly is locked to, and must turn with the axle. The principle of this gear may be more easily grasped if one remembers that the axle travels forward with the road wheel when in high speed or direct drive position; that it is held stationary when in low speed and that it will revolve backward when in the neutral or free engine position. The inner brake band serves as a running brake, and will retard the hub positively whether the gearing is in use or not.

A distinctive form of reduction gear mounted in the rear hub is that used in connection with the Harley-Davidson motorcycle. The gearing is of the bevel form and operates on the planetary principle. A shifting dog clutch is employed in addition to the master clutch which is of the friction type. When moved in one position, the master clutch drives the hub directly, and when it is pushed to the other position it drives the hub through the medium of the bevel-speed reduction gear. The complete device is not shown in the illustration (Fig. 181), as a clutch assembly and a friction brake must be added to the simple hub shown to complete the mechanism.

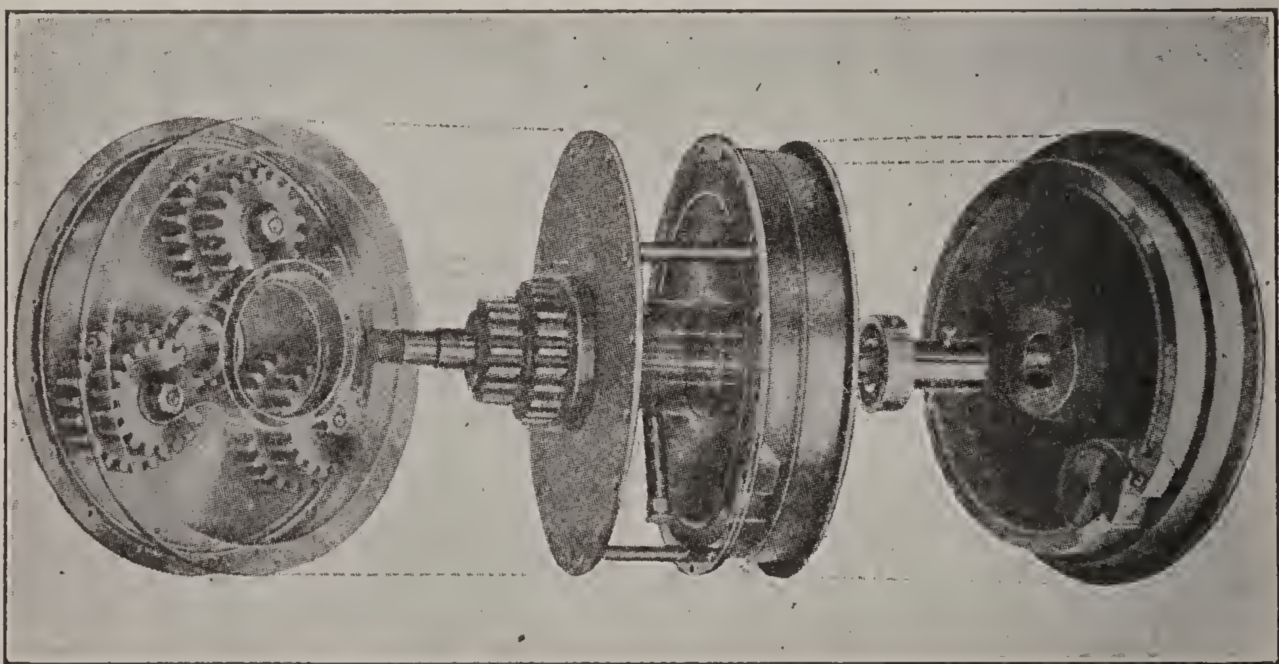


Fig. 182.—The Thiem Two Speed Hub Partially Disassembled to Show Arrangement of Mechanism.

Forms of hub gears working on the planetary principle have been evolved abroad which provide three forward speeds, but these are so complicated that they have received practically no application in America. There seems to be no good reason for the use of three-speed gears unless the motorcycle power plant lacks capacity, and, as the best American practice seems to be to provide a two-speed gear more for emergency use and to use power plants that will have sufficient power to overcome practically all normal resistance on the direct drive or high gear, the low gear is to be used only for starting, in hill climbing or in negotiating unfavorable highway surfaces. Practically all of the time the motorcycle is in use it may be operated on the

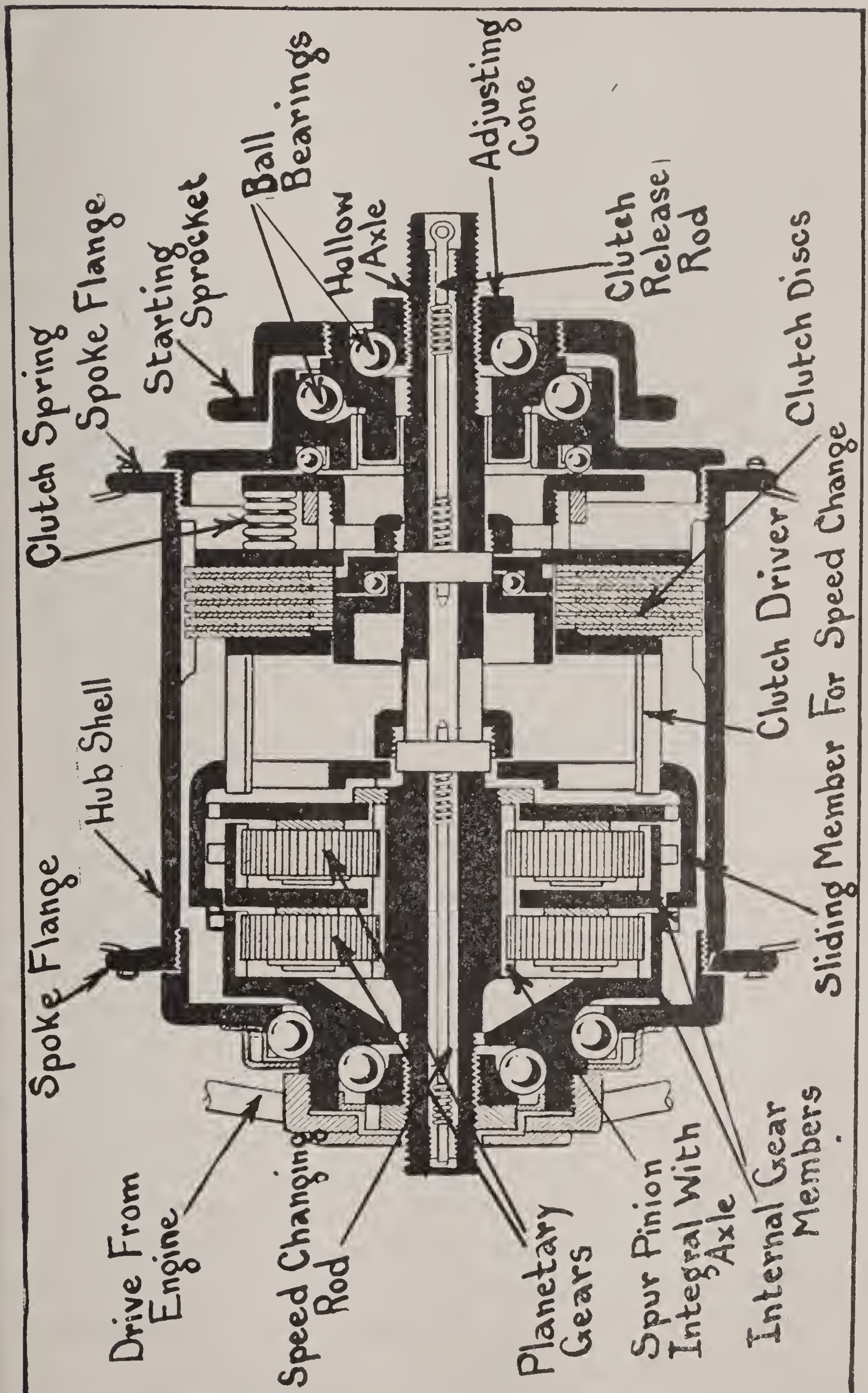


Fig. 182a.—Sectional View Showing Construction of the Sturmey-Archer Three Speed Planetary Rear Hub Gear.

direct drive or high speed. Fitting an intermediate ratio between the high and the low is not necessary when the power plant is of suitable proportions, though it might be of some value if the machine was under-powered, and the direct drive could only be used under exceptionally favorable operating conditions.

The Sturmey-Archer is a typical example of a three-speed hub, and it is said that the lowest gear ratio is to be used only when extremely high resistance must be overcome. The internal construction can be clearly understood by referring to Fig. 182*a*. When on the high gear, all parts of the hub are locked together solidly as the hub shell is driven directly from the driving member. On the second or intermediate gear, the drive is obtained from an internal gear member which rolls planetary pinions around a stationary central gear integral with the axle. The reduced motion of the planetary pinions is transmitted to the wheel hub by a driving member that clutches extensions from the friction clutch carrier. When the lowest gear of all is brought into action, the drive is through still another set of pinions and a further reduction in speed is effected. The direct drive is obtained by a plate clutch in the hub interior. It is said that a reduction of 47 per cent. in speed is obtained on the intermediate speed, and that a further reduction of 40 per cent. is secured on the low speed. The various speed changes are effected by moving a laterally shiftable member to the right or left, and the lowest speed ratio is obtained as the member is moved to the right. When on the high gear, the cup-shape driven member engages projections which are on the rim of the circular or internal gear member driven by the belt pulley. This means that the high gear is direct from the drive pulley carrier to the plate clutch. When the intermediate speed is desired, the sliding member engages with the internal gear carrying the first set of planetary pinions, and this internal gear meshes with and drives the second train of planetary pinions. On the lowest speed, the driven member engages with the carrier of the second set of planetary pinions.

Three Chain Systems.—A form of two-speed gear that has been used with some degree of success on European motorcycles is that shown at Fig. 183, in which a double sprocket is attached to the engine crankshaft, and two chains extend to the sprockets on the countershaft. Each of these sprockets may revolve independently of the

other or both may revolve free of the smaller driving sprocket used for driving the rear wheels. It is said that an advantage of this type of gear is that both speeds are direct and the friction and power loss due to the use of gear pinions is not present. It is also advanced that this system is extremely quiet in action, and that the clutches, which are of the internal expanding type may be used to give a free engine on either gear ratio.

The original form is undoubtedly the Phelon & Moore, which is

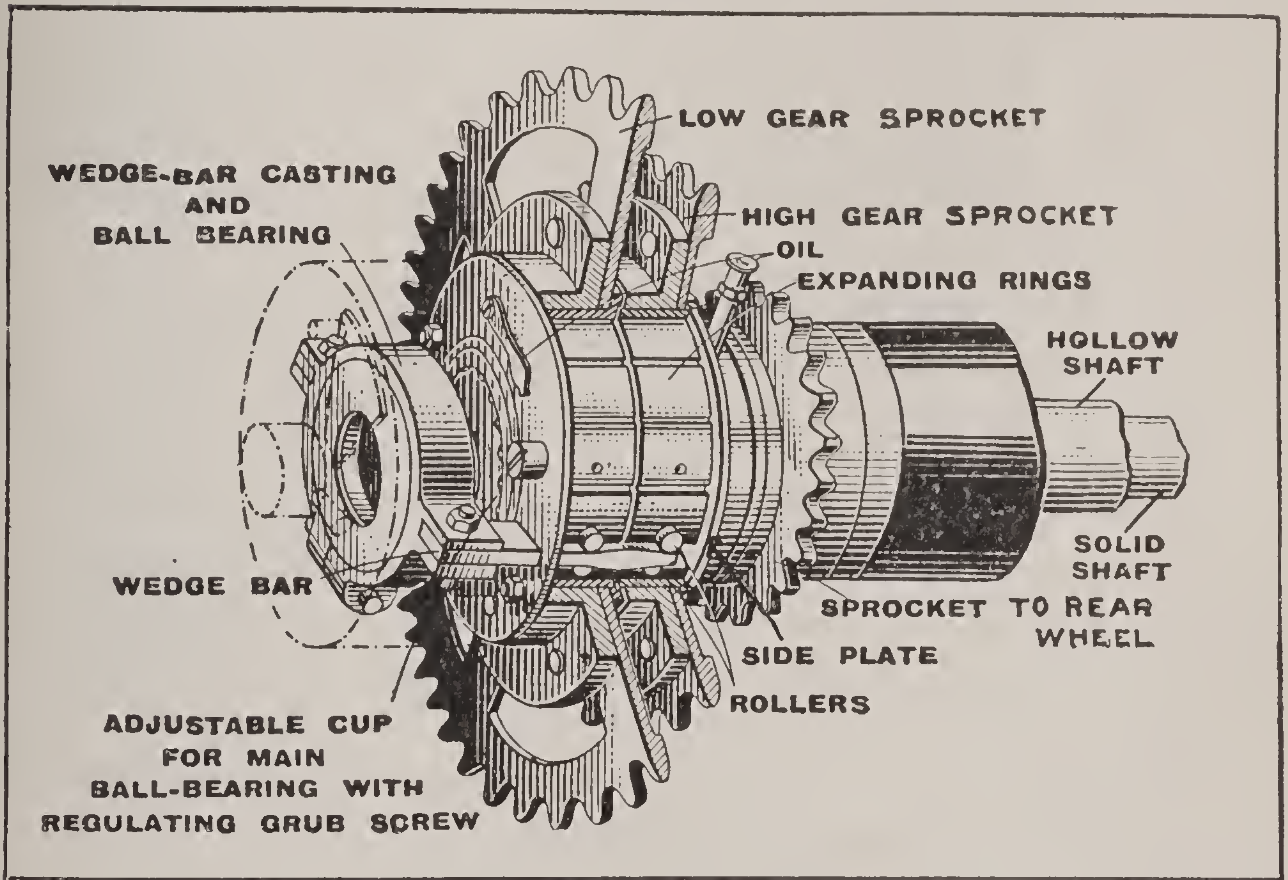


Fig. 183.—Phelon & Moore Two Speed Individual Clutch Countershaft Gear.

shown at Fig. 183. The low-gear sprocket, which is the largest, is the outside member, while the high-gear sprocket, which is the smaller of the two large ones, is the inside member. The clutch members act as bearings on which the sprockets revolve when the gear is in neutral position, but when expanded the shoes grip the interior of the drum carrying the sprockets very tightly and transmit the power to the small sprocket to which the brake shoes are fastened. The internal clutches are brought into engagement by sliding a wedged-shaped member to the right or left as the case may be, and spreading out the

brake shoes. In the form shown at Fig. 183, if the wedge bar is moved to the right, the brake shoe that clutches the high speed sprocket will be expanded, and the drive will be from the engine shaft to the countershaft through that member, while the low gear or larger sprocket will revolve freely on the brake shoes that are not expanded and which therefore act as a bearing for that member. If the wedge bar is moved to the left, the outside sprocket will be clutched to the driving member, and the smaller or high-gear sprocket will revolve freely on its brake shoes. It would seem that there would be considerable wear due to the movement of the sprocket carrier over the brake shoes, but the successful use of this form of change-speed gear for a number of years indicates the large surface of the bearing and the provisions made for lubricating them are adequate to prevent untimely depreciation.

The two-speed gear used on the Enfield (English) motorcycle is of the same pattern and is clearly outlined at Fig. 184. Either gear ratio may be brought in action by expanding the hardened steel bands A into one of the drums B, also of hardened steel, to which the chain wheels C are secured. The change in gear ratio is obtained in the same manner as in the Phelon & Moore by driving through the large sprocket for low speed and through the smaller sprocket for high speed. The expanding bands A are carried on internal drums D which take the drive, and which are keyed on the ball bearing shaft E that is employed to drive the sprocket F that connects with the rear hub. The clutches are engaged by cams cut into the block G, which is capable of sliding in either direction according to which gear is desired. The action of the cam is to force one of the pegs H against the split roller I, which forces open the band A until it engages with B, which is rotated by the engine. The object of splitting the roller I is to permit the clutch to pick up smoothly. The block G which contains the cam is moved by the rack J and the pinion K, which is operated by a vertical shaft and lever at the top of the crank. Three pairs of cams numbered 1, 2, and 3 are cut in G, each of these being .005 inch higher than the one preceding it. Should the band A wear to such a point that cam A is not sufficiently high to operate it, the member G may be turned around so the next larger cam will be used to expand the brake band. The practical application of

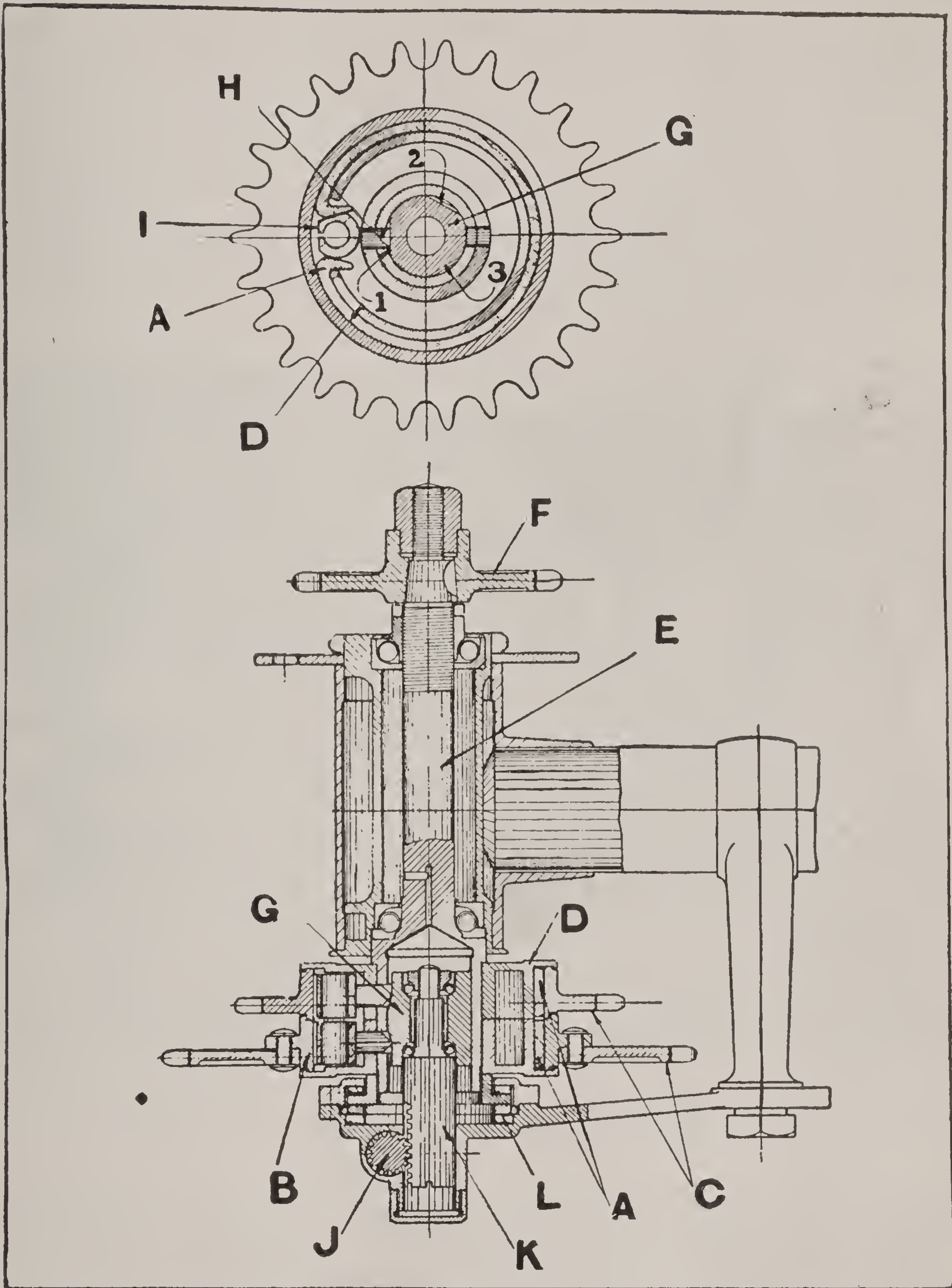


Fig. 184.—Two Speed Countershaft Gear Used on the Royal Enfield Motorcycle.

this gear to a Clement (French) motorcycle is clearly outlined at Fig.185.

Planetary Countershaft Gear.—Several of the American motor-

cycles employ a planetary reduction gear mounted on an extension projecting from the crank-hanger. A successful form, which is used on the Excelsior motorcycle is shown at Fig. 186. The drive from the motor is to the sprocket B attached to the planetary gear carrier A which also forms the male member of the friction clutch employed for direct drive. When it is desired to obtain a low speed ratio, the female member of the high speed clutch is pulled out of engagement with the male member, which is fixed and the V-shape bronze brake

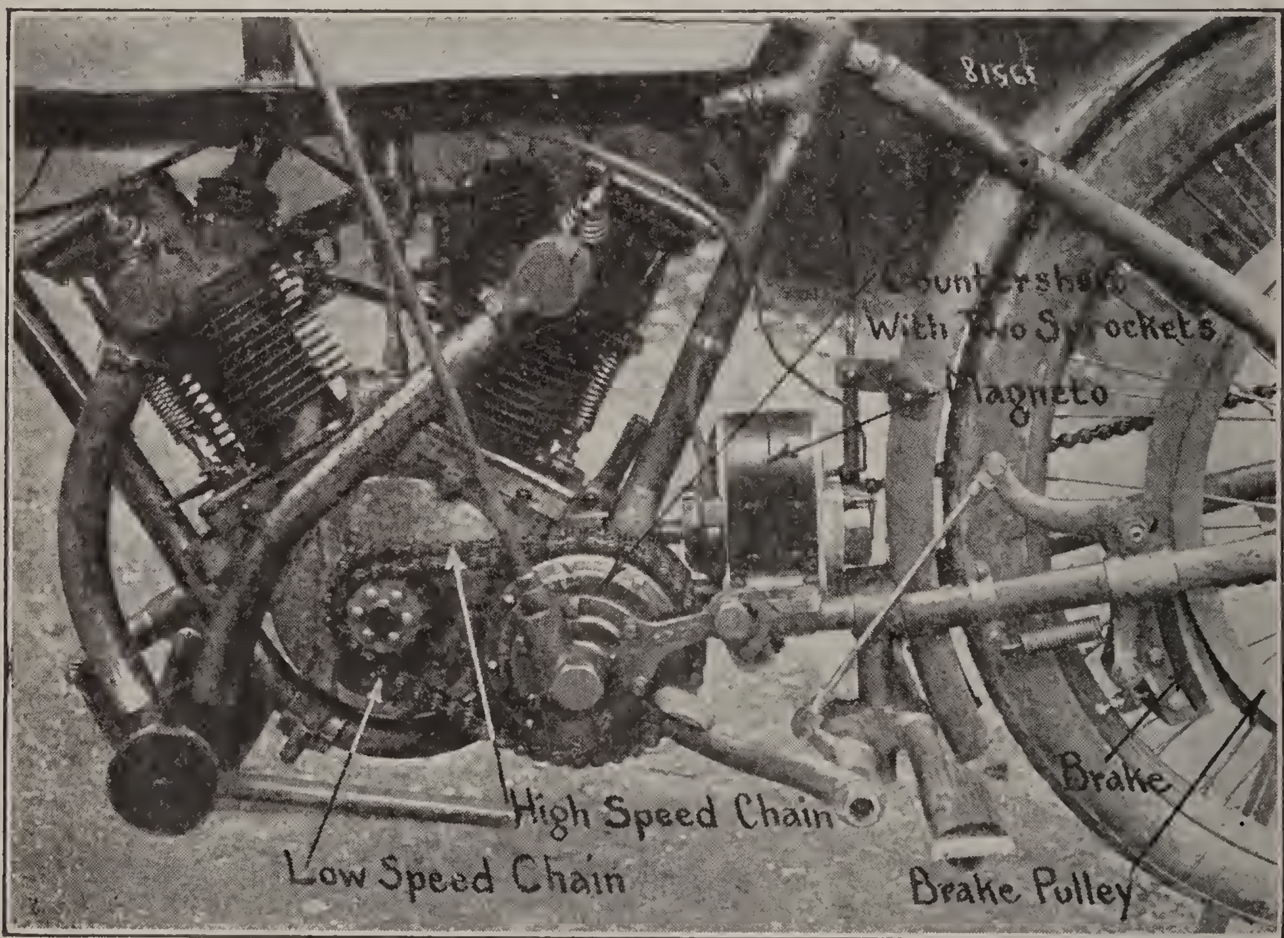


Fig. 185.—Three Chain Speed Changing and Driving System Used on Clement Motorcycle.

band M is tightened around the carrier I, to which is attached the gear H. As this gear is held stationary, the planetary pinions must rotate on their studs as they are carried around by the member A, and, as they turn at the same time, they drive the gear E, which is securely keyed to the bushing to which the sprocket G is fastened. To obtain a high gear ratio, the member M is released and the female member J, of the cone clutch, is brought into engagement with the male member so the drive is direct from the sprocket B through the

clutch members to the member F to which the wheel driving sprocket G is keyed. The member J is actuated by the operating worm K which is oscillated by the lever L. The entire construction is mounted on ball bearings so but little friction is present, and the liability of bearing depreciation is proportionately reduced. The practical installation of this gear, and the method of operation by a single handle, is clearly shown at Fig. 166. If the handle is moved in one direction the low speed is applied, and in the other position the high speed will

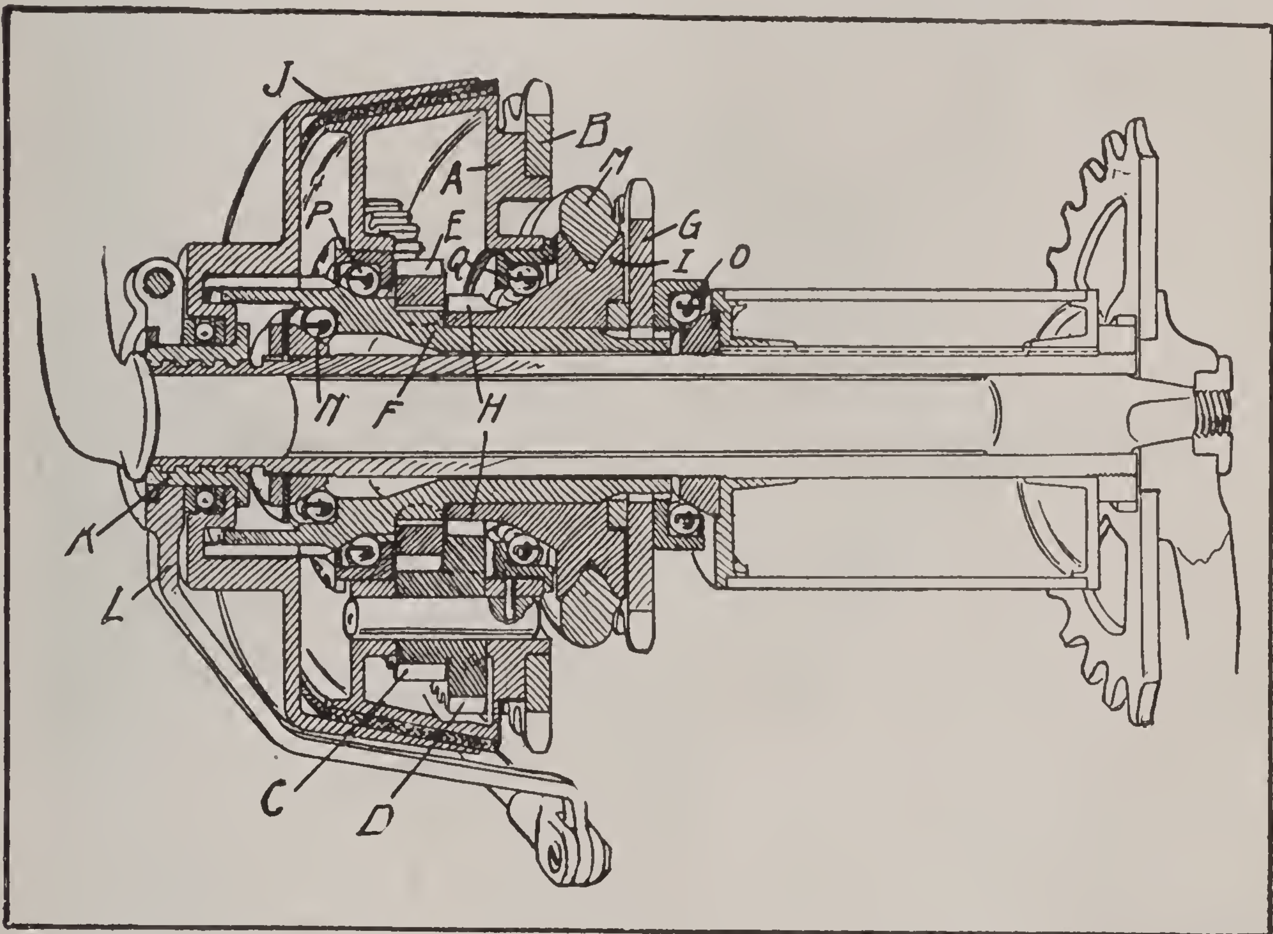


Fig. 186.—The Substantial Two Speed Planetary Gearset of the Countershaft Type Used on Excelsior Motorcycles.

be engaged. When in the position shown or approximately at the center of the notched quadrant, the gear is in the free engine position as neither the high-speed clutch J nor the low-speed friction band M is in engagement with their respective co-acting members.

Sliding Gear Type.—The sliding gear forms which have been so generally used in automobile practice have received but limited application in motorcycles. This is not as popular among motorcycle designers as the individual clutch systems are, because considerable

damage may result to the transmission gear when handled by the inexperienced rider. If attempt is made to change the speeds without releasing the main clutch member, the gear teeth will be burred or destroyed entirely. These pieces may get into the transmission and wreck the entire construction. It is contended by those who favor this construction that there is no more reason for the motorcycle rider to damage a transmission than there is for the automobile operator. As a general rule, the motorcycle is not intended to be

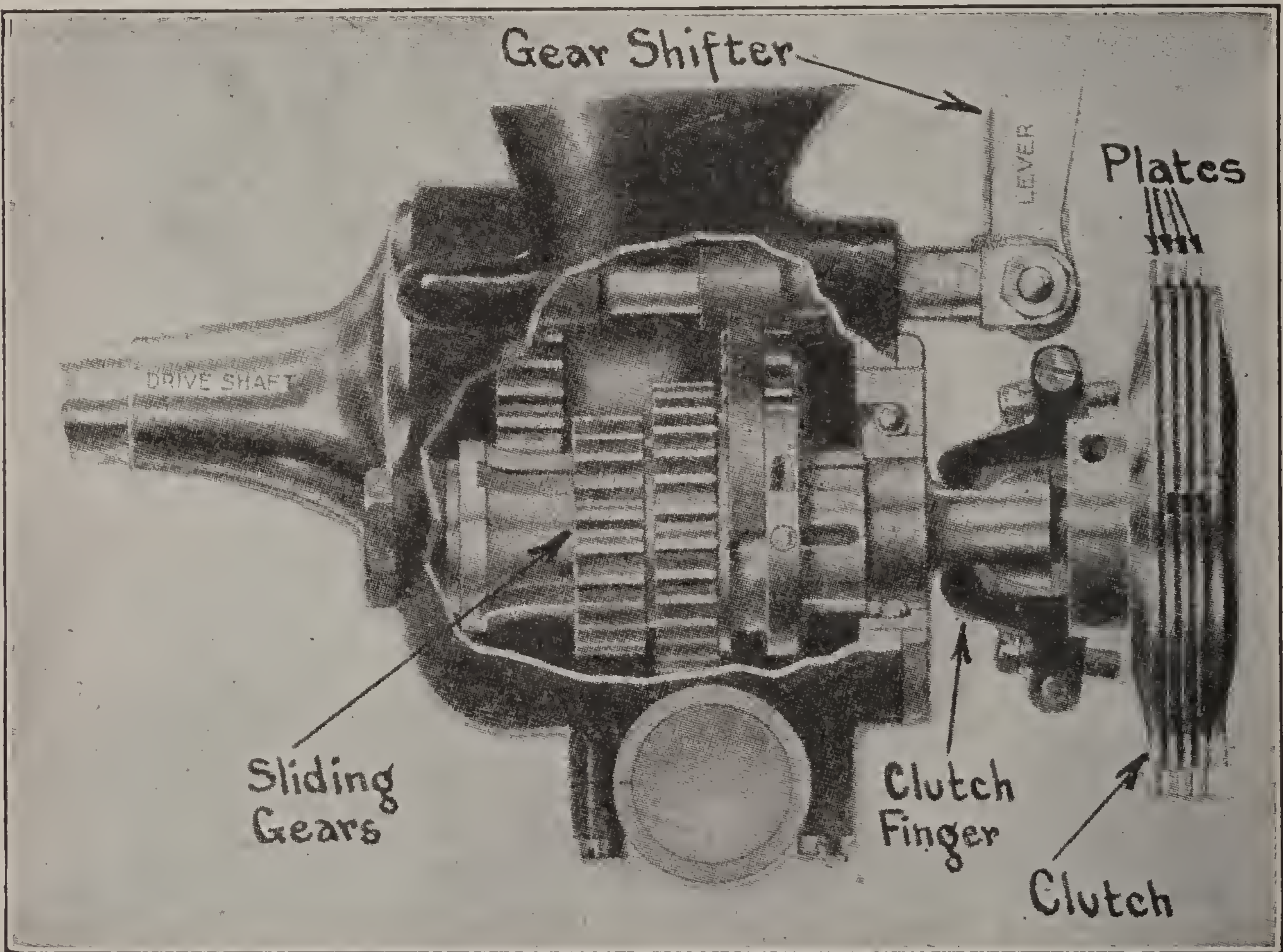


Fig. 187.—Pierce Two Speed Sliding Gear Transmission.

handled by expert mechanics, and the simpler the control system the more popular the motorcycle will be. In the individual clutch form, notably in the two-clutch planetary types, one cannot obtain a speed ratio without first declutching the engine. In the sliding gear, forms that are patterned after automobile practice, it is possible to shift gears whether the clutch is released or engaged.

A simple and effective sliding gear system which has been successfully used on Pierce motorcycles is shown at Fig. 187 with a portion

of the gear case cut away to show the arrangement of the sliding members, and in section at Fig. 188 so that the method of actuating the sliding members and the friction clutch simultaneously may be readily ascertained. This sliding gear transmission does not have the main disadvantage to that form of gearing, because when the shifting member is moved from one gear ratio to the other, the clutch is released automatically by the double cone arrangement, and will not be fully engaged until the shifting member is completely in mesh with one or the other of the gears attached to the propeller shaft.

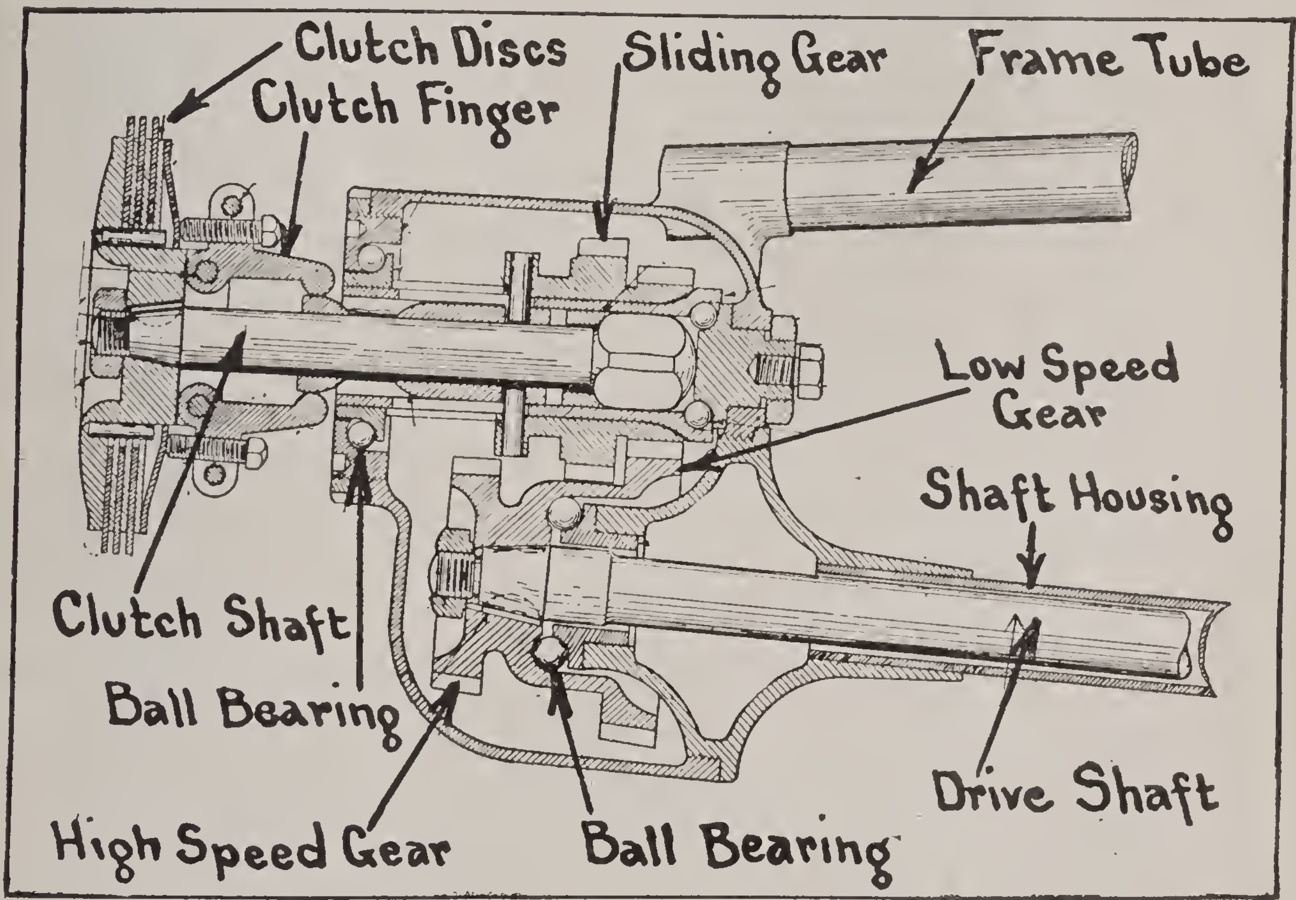


Fig. 188.—Plan View of Pierce Two Speed Sliding Gearset.

Power Transmission Methods.—A point on which considerable difference of opinion has always existed has been the best method of conveying the engine power to the traction member of the motorcycle. At the present time, belt, chain and gear drive are all used, and various combinations of these three forms are sometimes used in conjunction. Some systems of power transmission are more efficient than others, and, as a rule, those that are the most positive and that will transmit the engine power with minimum loss due to slipping are also apt to

have other disadvantages which would tend to favor the forms where the drive was by more flexible means.

The two conventional methods of driving a motorcycle are outlined at Fig. 189. The first system to be applied, and the one that was formerly the most popular, is by leather belt, which may be any one of a variety of forms. The type illustrated is a flat belt of the form that has been so widely used in driving the machine tools of the mechanic, and practically all other forms of machinery for many years. The other, which is more positive, involves the use of chains and sprockets. The latter method of driving was used on the first automobiles, just as soon as it was definitely determined that the flat belt drive systems were not practical for the heavier forms of four-wheeled vehicles. These systems will be considered more in detail in proper sequence. Drive by gearing is general at the present time in automobile practice, and is followed to some extent by motorcycle designers. Either the bevel or worm gear drive may be used in connection with a shaft extending from the power plant.

The single-belt drive, either by means of flat or V-belt is the simplest power transmission system, because it is possible to obtain a degree of free engine action without the use of a clutch if a jockey pulley or idler is employed to tighten the belt. With a V-belt, it is necessary to use a free engine clutch of some form to obtain the free engine which is also true of the various positive driving means such as chains and gears. The system of transmission to use depends to a large extent on the individual preferences of the rider and designer, because each system has its advantages, and all have been proven practical. When it comes to a question of efficiency, the drive by single chain or V-belt is undoubtedly the one that will transmit power with the least loss. With a properly adjusted V-belt, there is practically no slipping, and a flexible drive is obtained. A certain amount of power is required to bend the belt over the pulleys, but this is probably no more than would be consumed by friction of the various members of the chain and the friction between the chains and sprockets.

The figures in the following table have been generally accepted by automobile designers, and apply just as well to similar driving systems used in motorcycle practice.

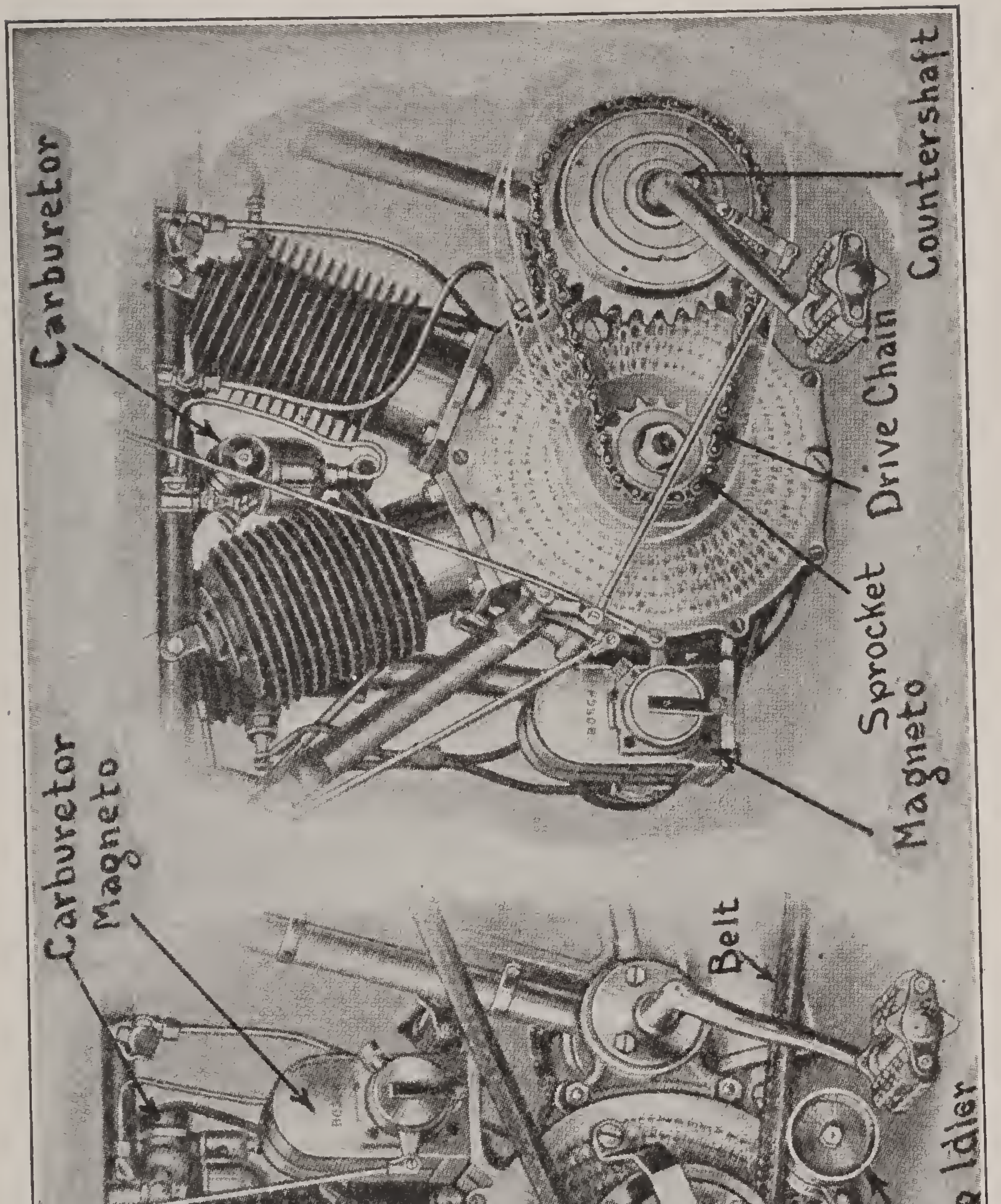


Fig. 189.—Illustration Showing Commonly Accepted Methods of Transmitting Engine Power to the Rear Wheel.

TRANSMISSION EFFICIENCY OF DIFFERENT TYPES OF MECHANISM (WORBY BEAUMONT)

Source of Loss of Power.	Amount of Loss Per Cent.	Efficiency Per Cent.
	....	100.0
When driving direct:		
One chain	3.0	....
One and one-half pairs of bearings	7.5	89.5
With epicyclic speed gear in operation, add	15.0	74.5
When driving direct:		
One set of gear	5.0	....
Two pairs of bearings	10.0	....
Partially active bearings	3.0	82.0
With change-speed reduction gear in operation, add	12.0	70.0

Carefully made brake tests have demonstrated that the power loss with a single-chain or V-belt drive is not greater than 10 per cent., whereas with a double-chain arrangement, which is the one generally used, about 20 per cent. of the power is lost in transmission. The type of change-speed gearing used also has some bearing upon the efficiency of the driving system. Gears of the planetary type will lose more power when on the low speed ratio than will either the sliding gear or sliding clutch forms, but at the other hand there is practically no loss when on the high speed because the assembly turns as a unit and the only power consumed is at the bearings. In either the sliding clutch or sliding gear forms, the countershaft is always in action due to the constant mesh gears, and some power is consumed at that point in addition to the main bearings.

While the positive driving systems are the most practical, some unconventional systems of propulsion have been devised and tried out in an experimental way. These are usually in the form of attach-

ments intended for application to the ordinary foot-propelled bicycle to convert it into a power-propelled type. One of these, which was exhibited at the recent motorcycle shows, is shown at Fig. 190, and propulsion is obtained by an air propeller of the same type used in aeronautical practice. It is said that with the latest forms of air propellers, more power can be obtained with a given engine size than will be delivered by marine propellers working in water. It is also claimed that the efficiency of a marine propeller will rarely rise higher than 60 per cent., while aeroplane propellers working in air may be

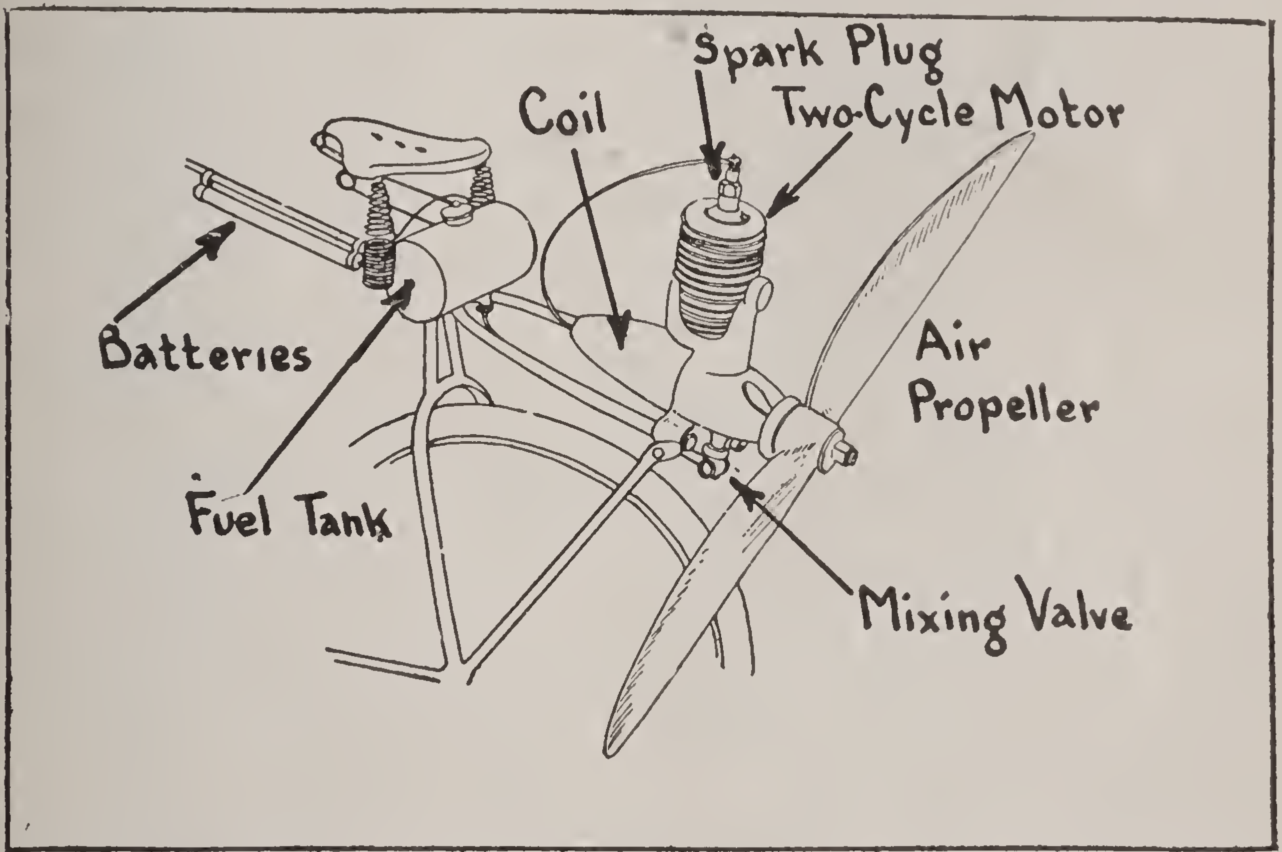


Fig. 190.—Unconventional Arrangement of Two-cycle Motor Driving Air Propeller for Bicycle Propulsion.

90 per cent. effective. The air propeller of the device shown at Fig. 190 has but little more spread than the span of the average bicycle handle-bars, and when used in connection with the small motor shown, the thrust is sufficient to push an ordinary bicycle 30 miles per hour over good roads. The engine is a three-port, two-cycle type, and with a bore of 2½ inches and a stroke of 2¼ inches, at a speed of 2,500 revolutions per minute, develops power ample for the purpose. The engine weighs but 16 pounds, and the entire attachment, including propeller, ignition system and fuel tank is said to weigh less than

40 pounds. While this system of propulsion is practical in air and marine craft and may have some degree of merit, it does not appear to be anything more than freak construction, and is only illustrated to show an unconventional method of bicycle propulsion. Such devices cannot give the satisfactory service obtained from properly designed motorcycles as the average bicycle frame, tires, etc., are not built with the idea of attaching mechanical power.

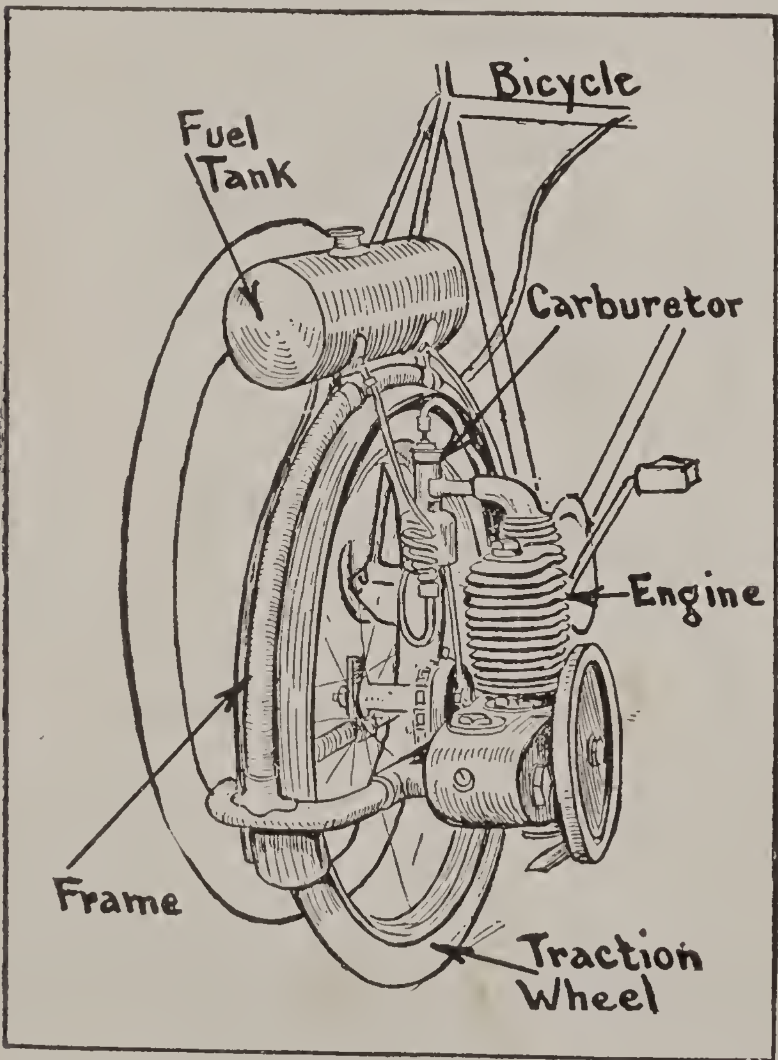


Fig. 191.—The Wall Auto Wheel, a Complete Self Propelling Power Plant Intended for Attachment to Ordinary Pedal Cycles.

The Wall Auto Wheel, which device is of English design, illustrated at Fig. 191, has considerably more merit than the air propeller, and has received practical application abroad. It consists of a separate wheel to which a miniature power plant is attached, and it is intended to be secured to the rear frame of a bicycle parallel with the rear wheel. The engine is air-cooled and has a bore and stroke of 2¼ and 2½ inches respectively. It is claimed that it will develop one horsepower, which is said to be ample to propel a bicycle at safe speed. The engine is of the four-cycle type, has an external fly-wheel, and includes a simple form of two-speed gear in an extension of the motor crankcase. The drive from the two-speed gear to a sprocket mounted on the wheel hub is by means of a short roller chain. The wheel is 22 inches in diameter and is carried in a substantial tubular framework to which the motor and fuel tank are secured.

This device has been produced for more than five years by the manufacturers, which have a factory in London, and, while it is not claimed that it will give the same results as a regularly designed motorcycle, still it permits of converting a pedal cycle into a self-propelled form, and on level roads and in practically all city work, it will undoubtedly be able to furnish power enough to drive the bicycle without any muscular exertion on the part of the rider. It is said that the two-speed gear makes it possible to climb all reasonable grades. An attachment of this kind can be used only on good roads and under favorable conditions, but the device is novel, thoroughly practical and probably will appeal to people of conservative temperament who will be satisfied with medium speed, and who do not intend to use the device in touring. The American rights have been acquired by a prominent manufacturer, and if it successfully stands the test that it is now undergoing it will be marketed in this country.

Belt Drive Systems.—Before describing the various systems of power transmission by belt, it may be well to review the advantages advanced by those who favor that form of transmission. One of the most important claims relates to the flexibility of belt drive and its power of absorbing the road shocks and machine vibration, which, it is contended, results in minimum depreciation of the power plant. It is also claimed that the reverse is true of the positive driving system which transmits the road shocks to the entire machine. The belt running over pulleys is silent because if a flat belt is used it is endless, and there are no metallic parts to strike and click. A V-belt may have a metallic coupling but this does not come in contact with the pulleys, and is therefore equally silent. Another feature of belt drive is said to be the absence of complicated parts. The conventional form of belt transmission consists of two grooved or flanged wheels, a connecting belt and a coupling, if a V-belt; or an idler or jockey pulley, if a flat belt. When a belt stretches, the rear wheel may be adjusted to compensate for the increase in length. It is said that the rider of a belt-driven machine experiences no discomfort from any irregularities of motor operation, as the flexible belt will take care of sudden changes of speed. Should a motor stop suddenly, as by breaking or sticking of some of the important internal parts,

a belt will slip sufficiently to enable the rider to retain his place on the machine. A rigid form of drive would be apt to result in a sudden stop, and throw the rider.

The factor of cleanliness is also given some consideration by the belt enthusiast, and it is evident that belts are naturally more cleanly because they do not need the lubrication that is necessary with chain drive. With the various positive driving systems, it is imperative that the parts be maintained in absolute alinement or there will be considerable depreciation of the mechanism and loss of power. With

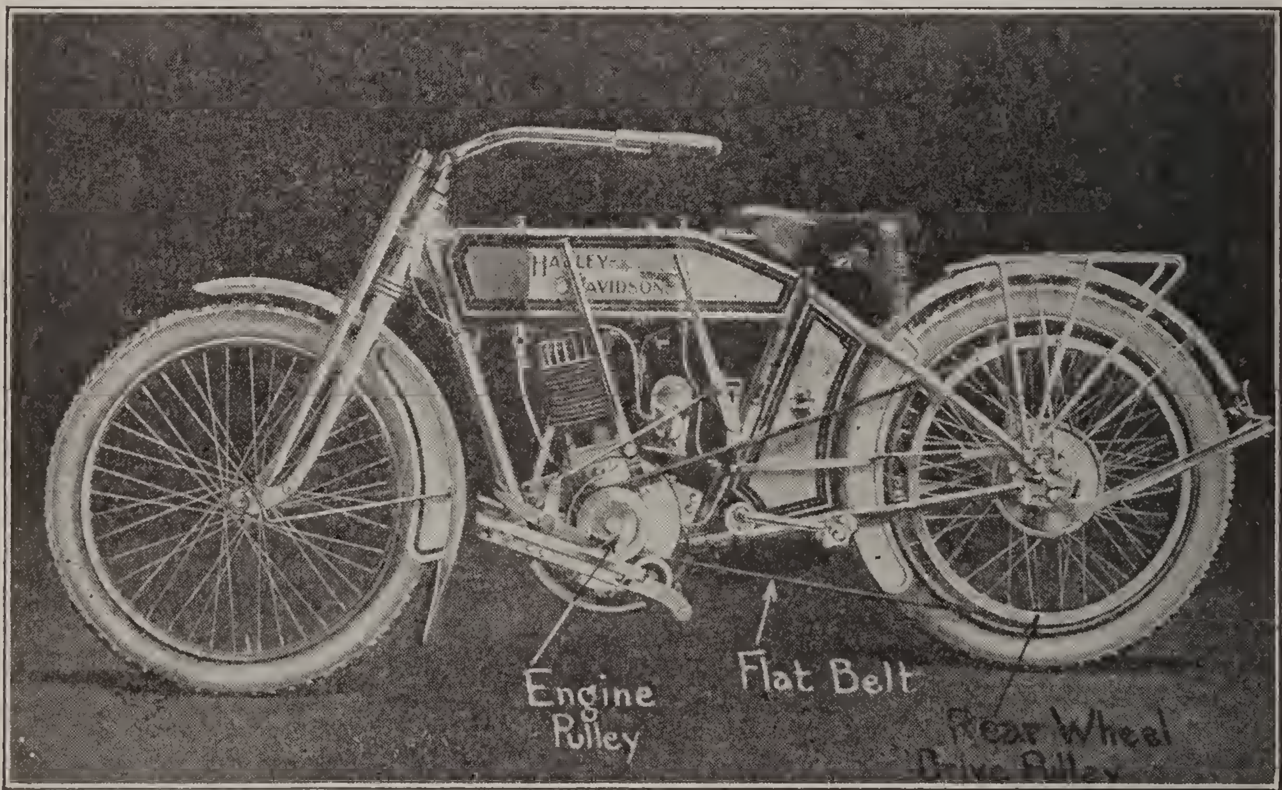


Fig. 192.—Harley-Davidson Five Horsepower Single Cylinder Motorcycle With Flat Belt Drive.

belt drive, any slight misalinement does not produce appreciable wear, and there is but little loss in transmission efficiency due to this condition. It is the belt that depreciates and not the pulleys, as these frequently outlast from three to five belts before they become worn enough to reduce the efficiency of the drive. If one considers the chain transmission, defective alinement means that the chain or sprockets, and in most cases both, will wear unduly, and have a material reduction of the useful working life. When a chain or its sprockets are worn, efficiency of drive can only be restored by renewing both members. It is a known fact among mechanics that a new

chain will not work well on worn sprockets, nor will an old chain function properly on new sprockets. The following summary of the advantages of belt transmission is given by a prominent manufacturer of these elements: Belt transmission causes less trouble and is less expensive than other forms of drive, because it is not seriously affected by a loss of alinement, which causes other transmissions to wear appreciably and frequently results in costly replacements. The flexible transmission insures minimum wear of the power plant, because the elastic driving medium will transmit fewer road shocks than

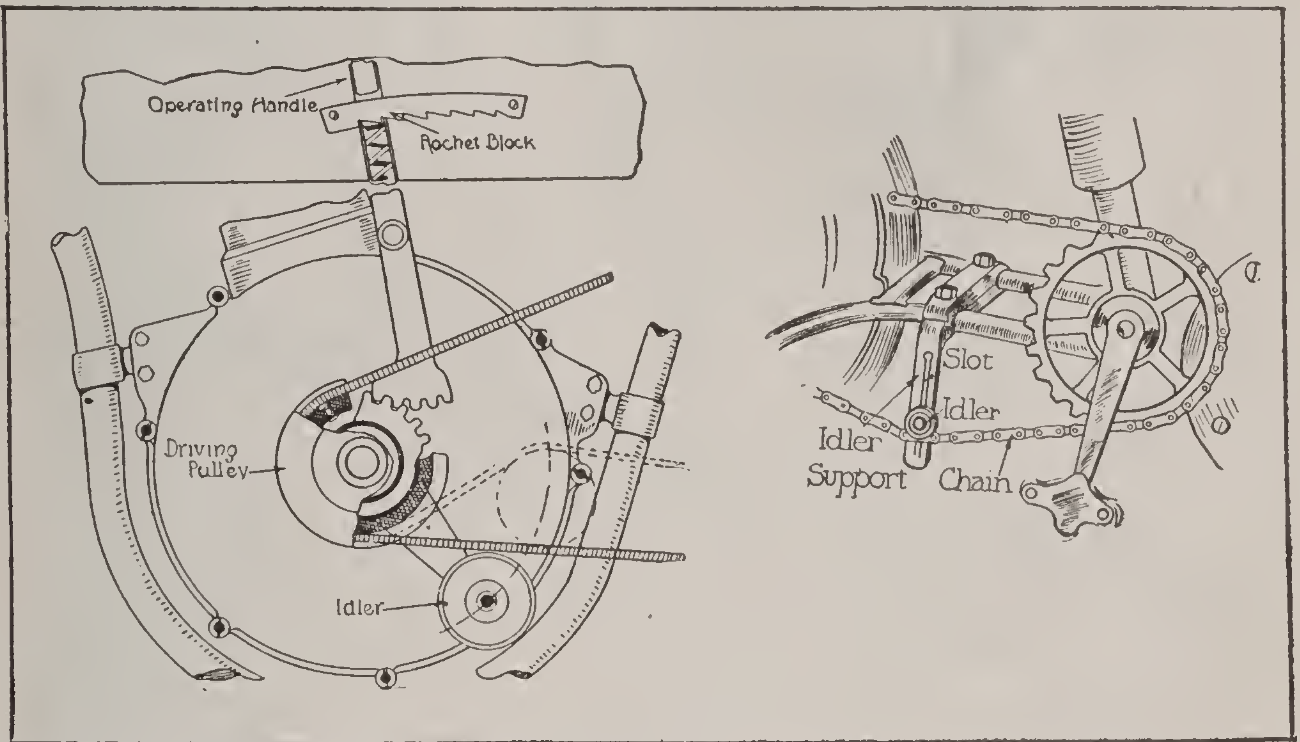


Fig. 193.—Showing Construction of Typical Idler Pulleys for Augmenting Tension of Driving Belts or Pedaling Chain.

the positive form. This means that there is less wear on bearings and gears because of the slipping under abnormal loads, such as quick starting, rapid acceleration, etc. These same features also contribute materially to the comfort of the rider because of smooth action. It is the least complicated, and therefore it is the least liable to get out of order. The feature of silence is also commendable, as drive is by leather to metal contact instead of metal to metal connections.

The application of flat belt drive to one of the Harley-Davidson models is shown at Fig. 192. The method of operating the belt idler or jockey pulley on this machine is clearly shown at Fig. 193. The idler is carried at the end of a bell crank which has a segment of a

gear as its other member. These gear teeth engage with suitable members formed at the lower portion of the operating handle. As the handle is pulled toward the rider, the idler pulley moves on an arc of a circle having a radius equal to the center distance between the idler pulley bearings and the pulley center. The flat belt may be normally loose when the idler is in the position shown, but when the pulley is raised to the position indicated by the dotted line the

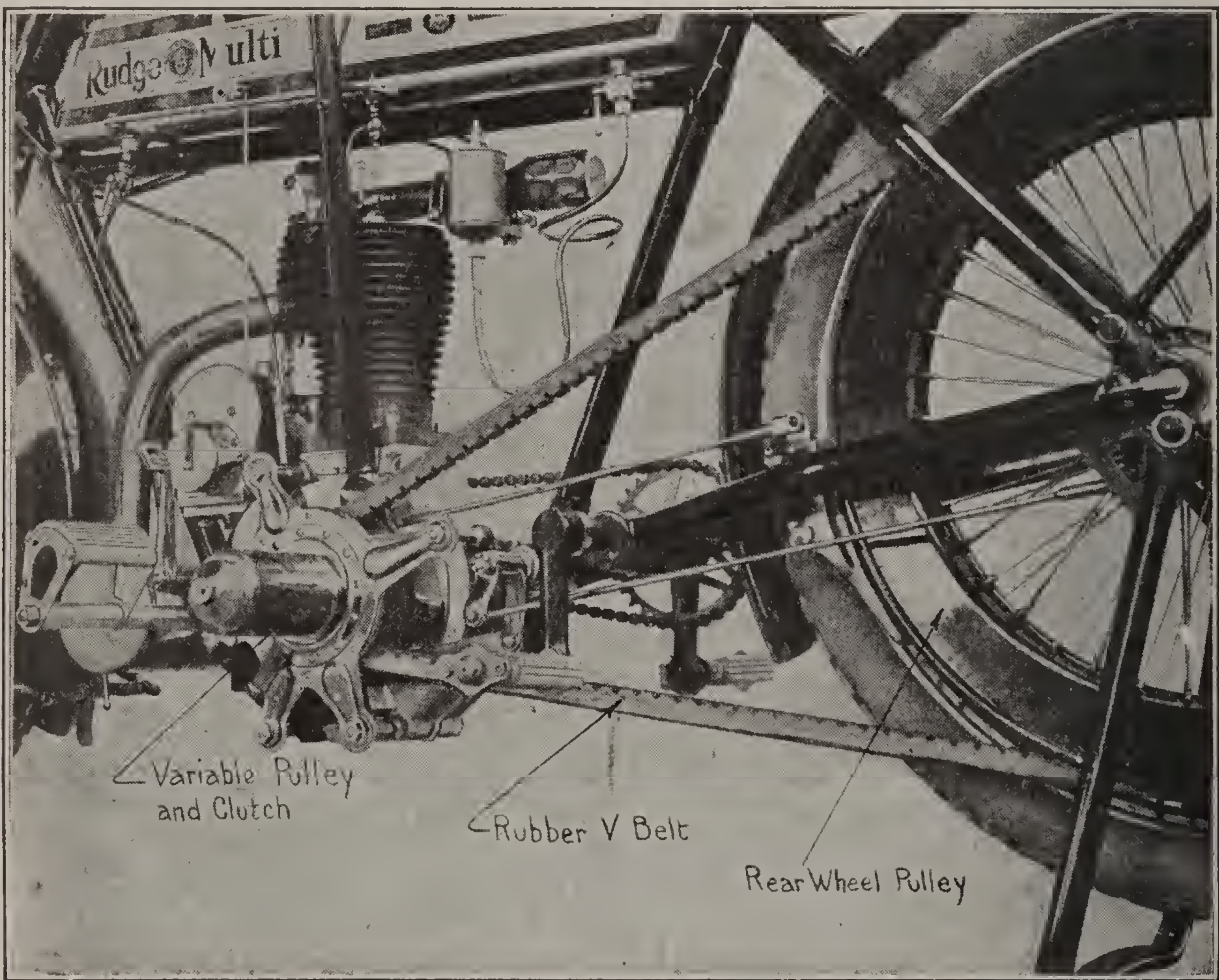


Fig. 194.—View of Power Plant and Drive of the Rudge-Multi Motorcycle, Showing V Belt Transmission.

belt is made to hug the engine pulley very closely, the effective arc of contact between the belt and the driving pulley is increased and a more effective drive obtained. The view at the right of Fig. 193 shows one method of compensating for the variation in pedal sprocket centers as the rear wheel is moved to allow for belt stretch. A small ball-bearing idler is mounted in a slotted support, and is moved down in the slot to tighten a loose chain, and moved up to loosen a tight

chain. Many of the belt drive machines still retain the pedaling chain, and suitable provision must be made to keep that member in proper adjustment.

The V-belt drive which is used on the Rudge-Multi is shown at Fig. 194. The belt is a combination rubber and canvas form, and is utilized in conjunction with a variable pulley and friction clutch attached to the power plant.

Types of Driving Belts.—The various forms of belts that have been applied for motorcycle propulsion are outlined at Fig. 195. That at A is a twisted, round rawhide belt that was the first form to be used

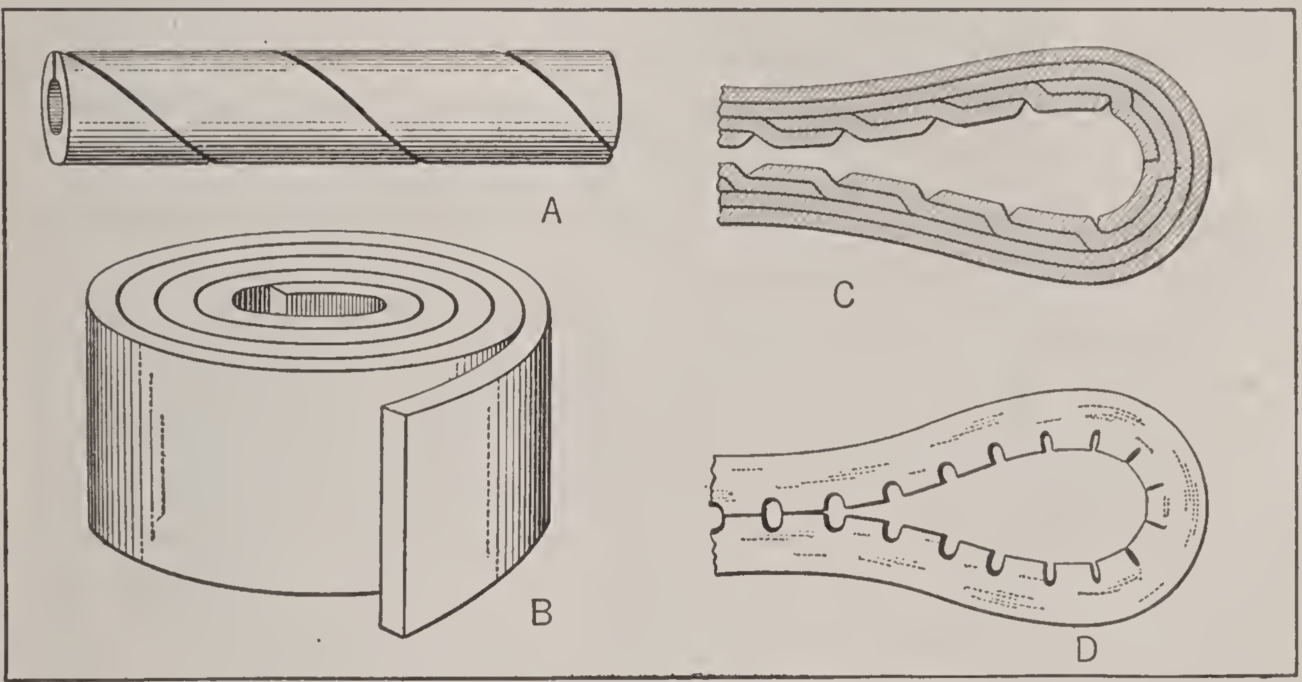


Fig. 195.—Forms of Motorcycle Driving Belts. A—Twisted Rawhide. B—Flat Leather Band. C—Duco-Flex Leather V Form. D—Shamrock Gloria, Rubber and Canvas Belt for V Pulleys.

in motorcycle service. It had one advantage, and that was that its tension could be increased when desired by twisting the belt more closely together. A grave disadvantage was that it was materially affected by changes in weather, and was apt to stretch very much when wet, and shrink very fast when drying. This form was soon succeeded by the flat belt depicted at B, which is the same form that has been widely used for power transmission in our workshops. The V-belts were the next to receive general application. These may be divided into two main classes, one of which comprises all belts made of leather, while the other includes those made of other materials,

such as canvas and rubber vulcanized together. A typical leather V-belt, the Duco-Flex is outlined at C, and a rubber belt, the Shamrock-Gloria is depicted at D.

Various expedients are used by designers to secure flexible V-belts, as it is imperative that a belt bend easily in order that it may follow the contour of the small driving pulley attached to the engine crankshaft. The special construction outlined at C involves the use of two continuous layers of leather to which are attached overlapping pieces that are to form the third and fourth plies of the belt. In the moulded rubber and canvas forms, shown at D, notches are cut in the bottom of the belt at frequent intervals, which permit the belt to describe a curve of small radius when the spaces close in as indicated, due to the bending of the belt.

The usual construction of a leather belt of the V-form is outlined at Fig. 196. The belt consists of two continuous plies of leather that are riveted together between leather blocks with tubular rivets. The leather block used on the bottom of the belt is not as long as that on the upper part, and this construction permits of considerable flexibility. The Wata-Wata, an English belt, is shown at Fig. 197. In this construction, the upper and lower plies of the belt are separated by spacer blocks of arch formation, which allow the belt to bend around a circle of small radius because the lower portion or ply of the belt will fill the space between the blocks and permit the belt to bend easily. The ends of V-belts are fastened together by metal hook members which are made in a large variety of forms, one of which is shown in this illustration.

Another English belt which is a distinctive construction, and which is said to give very satisfactory service, is shown at Fig. 198. This is known as the Whittle belt, and is a composite structure made of steel links carrying suitable bearing pins spaced between leather links. The two leather links are fastened together by a short regular pattern wood screw as indicated.

Some of the forms of belt fasteners that have received a ready market are shown at Fig. 199. That at A is a simple form consisting of a pair of hinges having downwardly extending prongs to grip the belt, joined together by a simple hook member. The form at B uses a quick detachable hook which permits of some adjustment by using

hooks of different lengths. The form at C consists of a link of roller chain joining two simple duplicate V-shaped members carrying the screws for attachment to the belt. The wire hook depicted at D is the form of connector used with twisted rawhide belt. Another type of connector which provides some opportunity for adjustment is shown at E. When the belt stretches, the connecting member may be used to shorten the belt by changing its position. Instead of bearing at the extreme end one of the connecting members may be brought

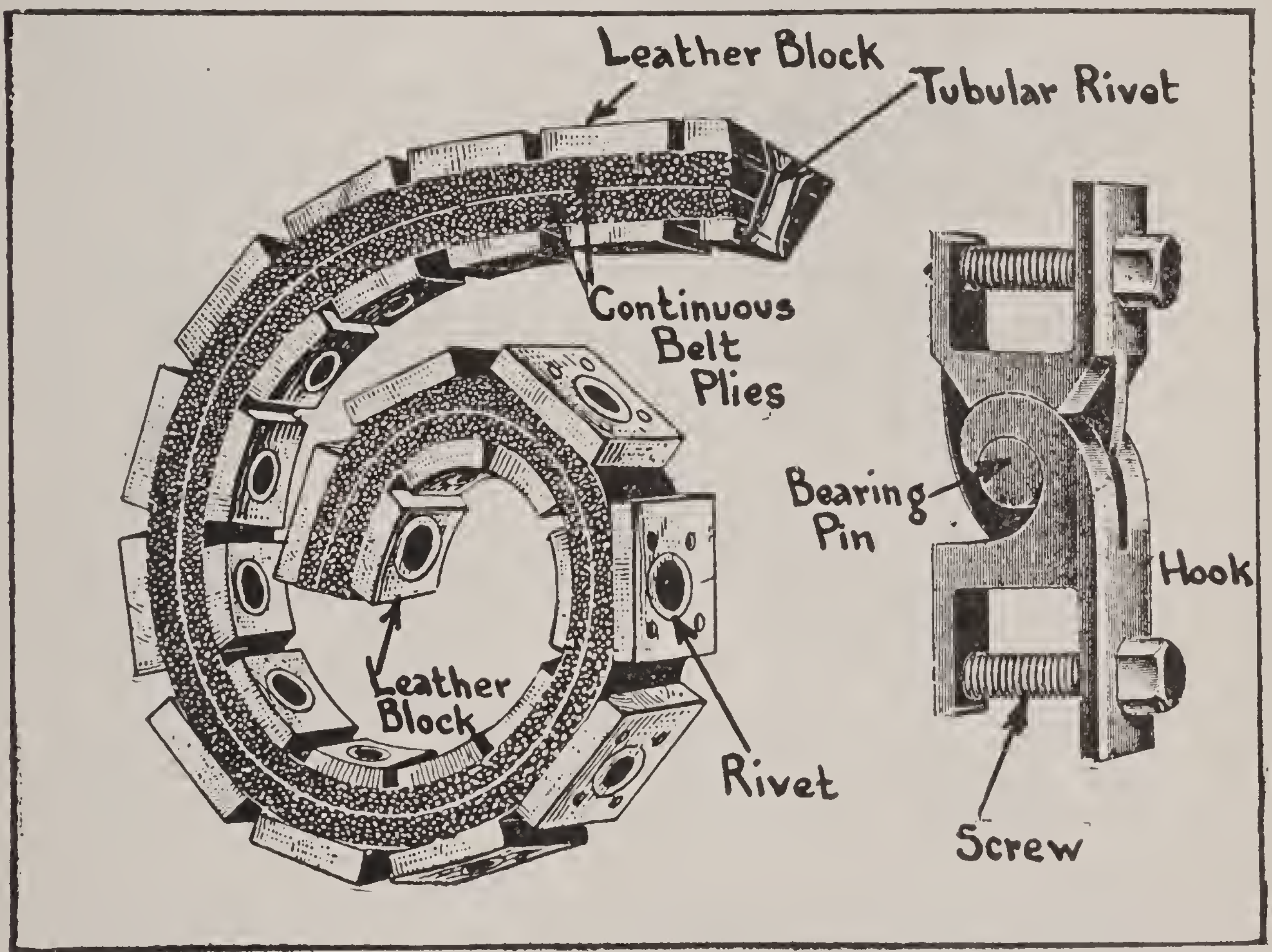


Fig. 196.—Typical Leather V Belt and Connecting Links.

nearer the other by placing it in the bearing at the upper portion of the connector ring.

Various tools are necessary to maintain belt efficiency. One of these, which is shown at A, Fig. 200, is employed to cut belting of the V-form smoothly and accurately. It consists of a suitable casting member carrying a sliding cutting knife guided by slots in the casing, which is forced down to sever the belt by a set screw bearing against the back of the cutting blade. The other set screw is utilized to clamp

the belt tightly against the movable lower plate which may be raised when desired to accommodate smaller sizes of belts. Practically all of the connectors used with V-belts require that holes be made in the belts to permit of passing the screw that clamps the connector to the belt through it. A punch for making these holes is shown at Fig. 200, B. This is a double member, and the thumb-screw to which the punch is attached may be placed at either end. When in the position shown it will punch one-inch belt, and if the screw is reversed,

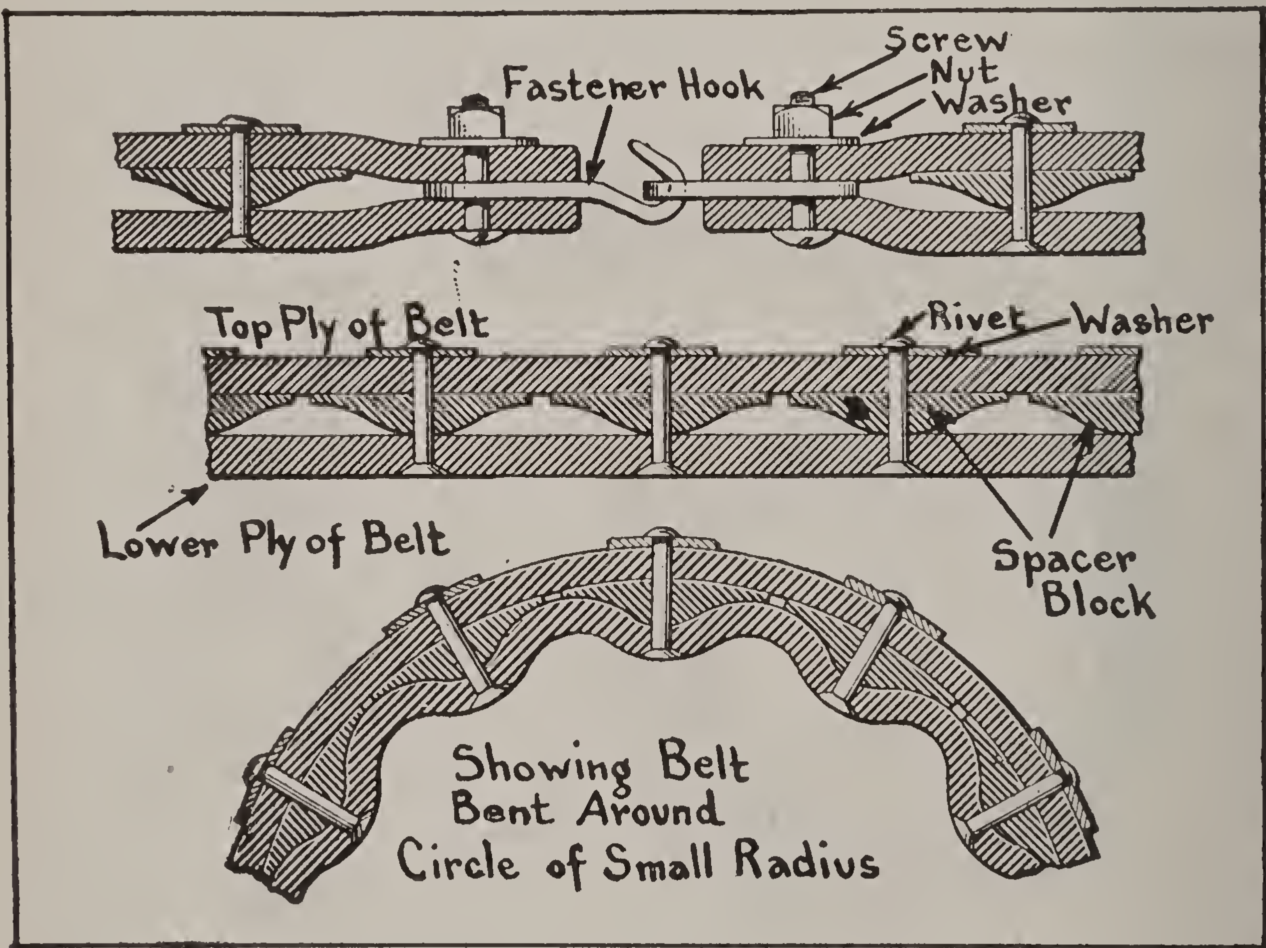


Fig. 197.—Showing Construction the Wata-Wata V Belt.

the device can be used for piercing seven-eighths-inch V-belt. After a belt has been shortened a number of times, a point will be reached where the ends will be too far apart to receive a standard connector of the simple form. In such cases, the links shown at C may be used to advantage because the center of the connector is composed of a block of rubber beveled off at the same angle as the V-belt. This grips the pulley and prevents slipping or noisy action which would be apt to result if a connector of the simpler form was used.

Standard Belts.—The regular pattern V-belt is made to run on pulleys that have the driving faces beveled so that the included angle between the flanges is 28 degrees. If trouble is experienced with slipping of a V-belt and the substitution of a new member for the old one does not cure the trouble, a gauge may be made of sheet metal and used as indicated at Fig. 201. If the pulley flanges are hollowed out, which would be apt to result after the pulleys have been in use for some time, this condition will be clearly indicated by the fit between the gauge and the flanges. Belts are made in a variety of

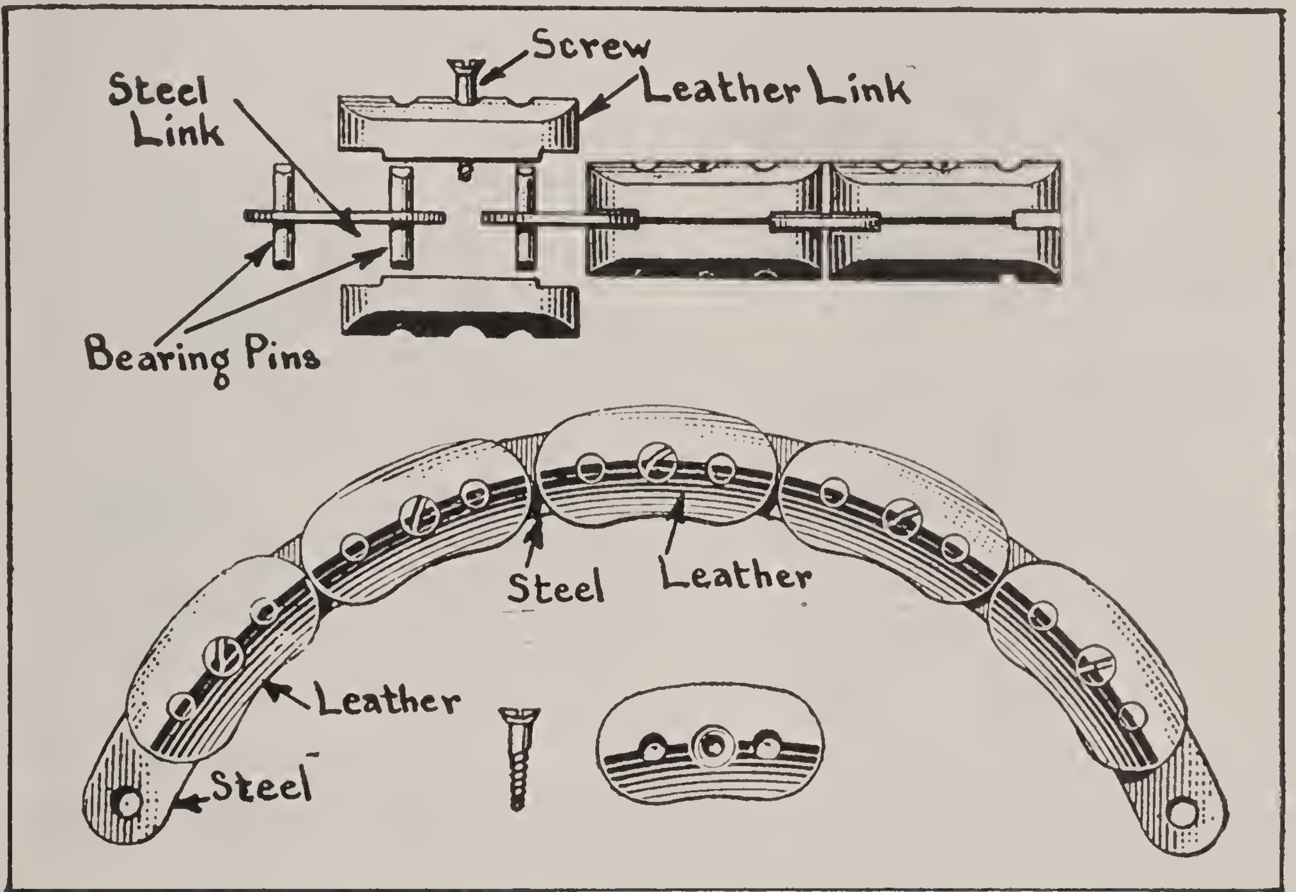


Fig. 198.—Unconventional Form of V Driving Belt of Whittle Design, in Which a Combination of Leather and Steel Links are Used.

widths, and are usually of special tannage because the ordinary oak-tanned leather used for belting in machine shops is absolutely unsuitable for the work demanded of a motorcycle drive. Chrome-tanned leather is generally used for belts because this produces a tough, sinewy material best adapted to resist oil, water and heat generated by excessive pulley friction. Chrome-tanned leather also has greater tensile strength than the oak-tanned and it will transmit more power. It is also more flexible, will not slip when wet, and is

not apt to curl on the edges or stretch as much as the belting made by the other processes.

Flat belts are usually made in two plies and will range from 1½ to 2½ inches wide, the variations in size being by increments of one-eighth inch. Naturally, the greater the amount of power to be transmitted, the wider the belt must be to take the augmented pull. The plies are not only cemented together but, in some instances, they are also stitched at the edges. The cement used should be heat and water-proof, and it is also necessary to stretch the belts a number

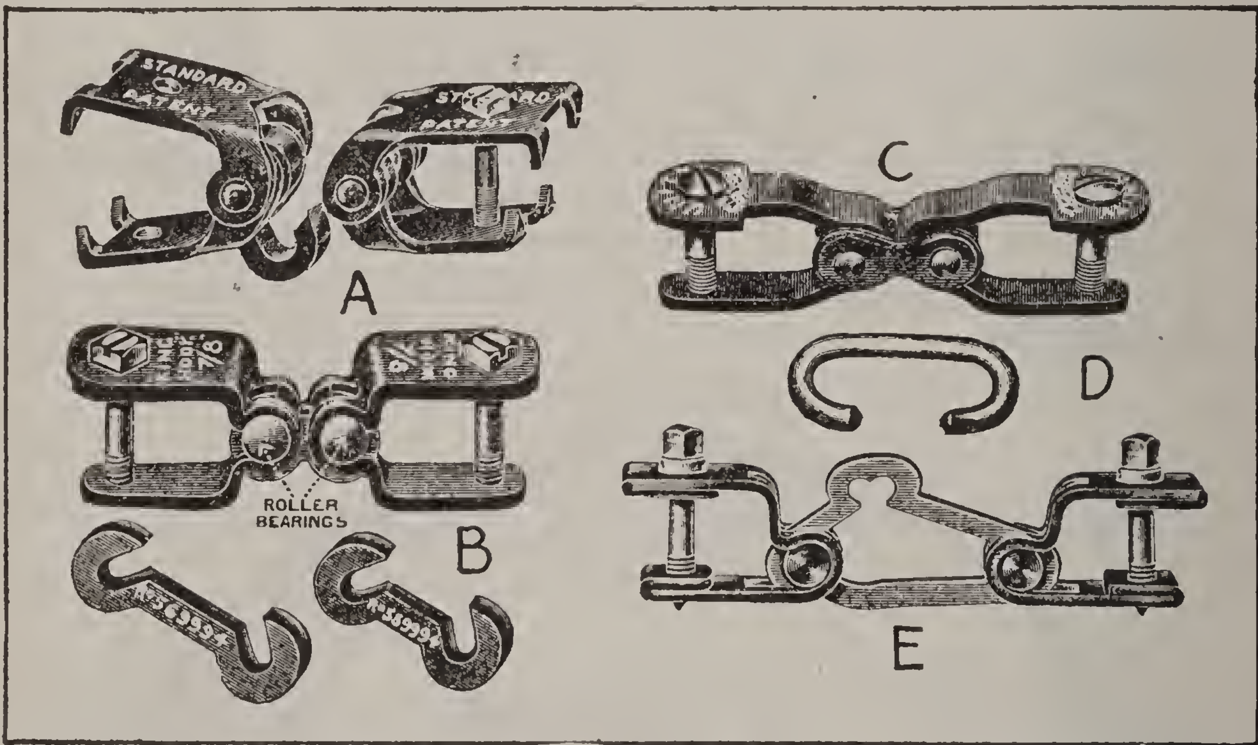


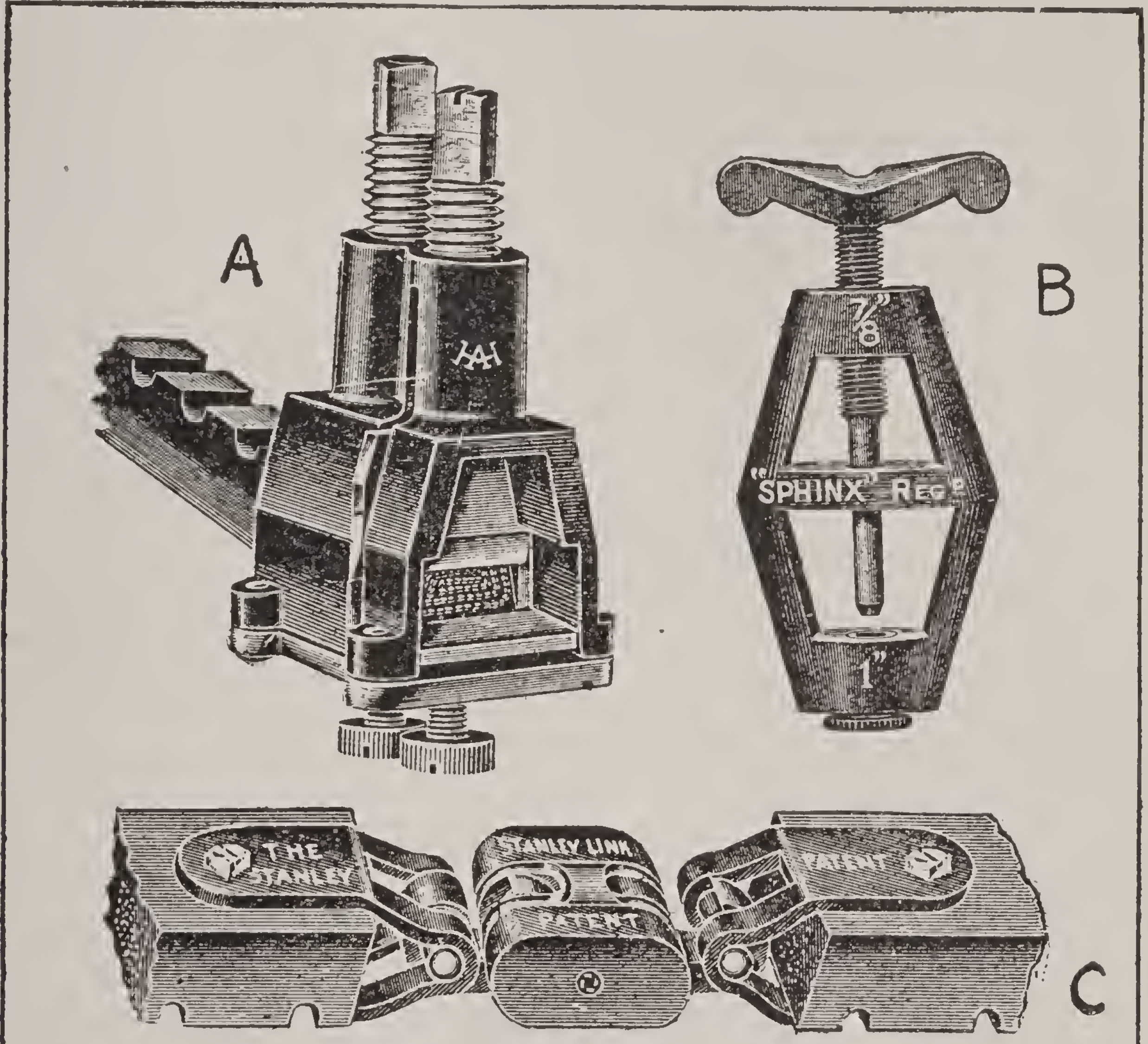
Fig. 199.—Various Forms of Connecting Links for Motorcycle Driving Belts.

of times after cementing before the belt is ready for use, to give them an initial permanent set.

In making V-belts, two continuous plies in the forms intended for medium-powered engines, and three continuous plies on the forms devised for larger power plants are cemented together, and then special two-ply blocks are riveted to the continuous plies with steel rivets to obtain the required depth of friction surface. The blocks are of special construction, in order to enable the belt to conform more readily to the small engine pulleys. All standard V-belts, whether made of rubber or leather have a 28 degree included angle.

Belts vary in length from 7 to 9 feet, and the average length is about

8 feet 6 inches. Leather belt is used almost exclusively in the United States, though the rubber and canvas V-belt is more popular abroad. The advantage of rubber belting is that it is not apt to be affected by water, but it is not as flexible as the leather belt, nor does it have the same amount of adhesion to the belt pulleys. Flat belt pulleys are usually made of cast iron covered with a layer of leather, or a lagging



"Stanley" Spare Rubber Link.

Fig. 200.—Useful Appliances for Repairing Rubber and Canvas V Belt.

of woven wire-asbestos fabric, in order to secure greater adhesion between the belt and pulley. Owing to the large amount of surface on the rear driving pulley, it is not customary to provide any lagging on that member, as sufficient adhesion is obtained without it.

Lagging is not necessary on V-belt pulleys, because the tendency of the belt is to wedge itself in the space between the flanges, and as

the power developed by the engine increases, the adhesion augments proportionately because of a greater wedging effect. The four-ply V-belts vary in width from ¾ inch to 1¼ inches by increments of one-eighth inch, and the five-ply belt, which is intended for use with powerful twin motors will vary from 1⅛ inches to 1½ inches in width. There is no intermediate size between 1¼ inches and 1½ inches V-belt. The width of a V-belt is always measured at the top.

The writer has made a careful analysis of belt drive machines produced by American manufacturers for several years, in order to arrive at the average practice as relates to the sizes of belts used with various motor horse-powers. The following tabulation may prove useful for reference:

Single Cylinders, up to 2½ horse-power (Old Style Machines):	
Flat Belt	1¼ to 1½ inches wide
Twisted Rawhide	⅝ to ¾ inch dia.
V-Belt	¾ to ⅞ inch wide
Single Cylinders, 2½ to 5 horse-power:	
Flat Belt, 2-ply	1½ to 1⅝ inches wide
V-Belt, 4-ply	⅞ to 1 inch wide
Two Cylinder, up to 7 horse-power:	
Flat Belt, 2-ply	1⅝ to 1¾ inches wide
V-Belt, 4-ply	1 to 1¼ inches wide
Two Cylinder, up to 9 horse-power:	
Flat Belt, 3-ply	1¾ to 2¼ inches wide
V-Belt, 5-ply	1¼ to 1½ inches wide

Advantages of Drive by Chains.—The credit of being pioneers in the application of chain drive on motorcycles belongs to the Hendee Manufacturing Company in this country, and to Messrs Phelon & Moore in England. It was adopted by both of these makers on standard stock products in the year 1900, and both have been unusually loyal and have consistently advocated chain drive ever since. Other makers followed their example, but they either did not realize that in order to enjoy the real benefit given by the chains that the machine must be especially designed for them or else the majority of motorcycle engines in those days were not as smooth-running as the creations of to-day, because for a time, the chain transmission

was not generally favored on account of the alleged harshness of the drive.

Other influences, however, were at work, and the consequent improvement and increase of power in the engine, and the use of side cars, showed that the belt drive was not always adequate for powerful motors pulling heavy loads unless made of excessively large size. Various cushioning devices were also evolved in order to relieve the mechanism of the shock, due to positive transmission of power and a review of current practice indicates that chain drive is standard on most of the best-known American machines, and is generally accepted as producing a moderately silent, smooth-acting and reliable transmission. In Europe, the belt is still the most popular form of power transmission, but indications point to a gradually increasing appreciation of chain drive in both England and France.

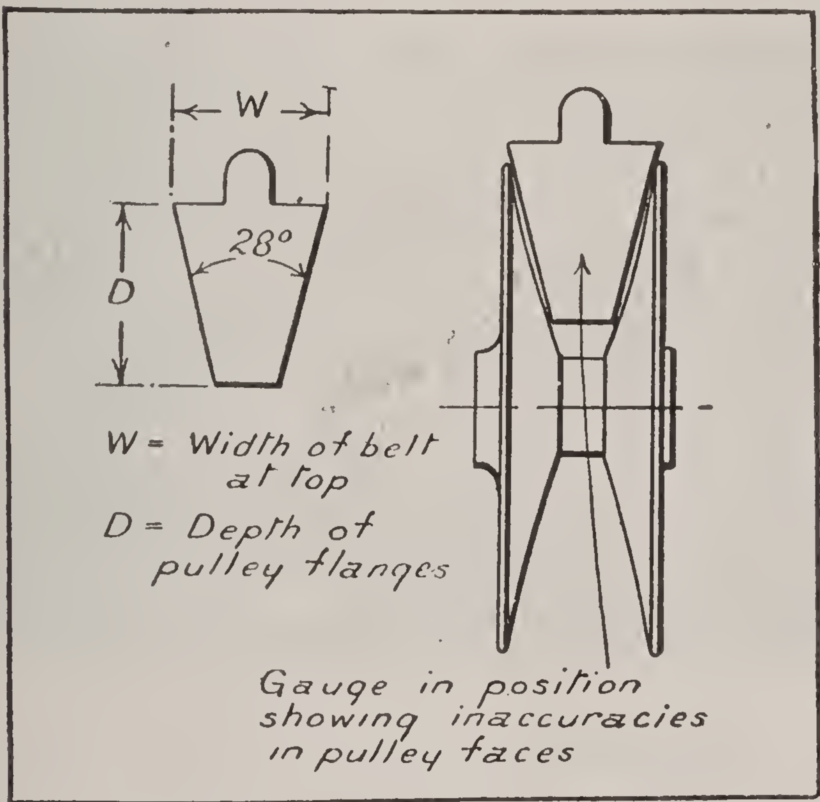


Fig. 201.—Defining the Application of a Gauge for Testing Accuracy of Flanges of V Belt Pulleys.

There has never been any question regarding the positiveness and efficiency of chain transmission. In fact, the first objections advanced against it was that it erred in being too positive. The early forms of motorcycle engines, especially the big single cylinder power plants did not deliver a very even turning moment as the power was applied as a series of violent shocks. As previously stated, the belt equalized the drive to some extent by slipping and stretching while the chain, as originally applied, transmitted the shocks to the machine, and thus not only caused considerable wear on the tires but promoted the discomfort of the rider. The introduction of better balanced engines and more especially of various com-

pensating clutches and cushioning devices of one sort or another promoted the general adoption of chain drive.

An important advantage of chains is that these do not need to be tight to transmit power, which is absolutely necessary in connection with the use of belts, especially the flat belt. In order to reduce belt slip, it is necessary that they be tight, and the belt pull causes considerable unnecessary friction on the engine bearings, especially of the plain type. With the chain, no initial tension is necessary, and the frictional loss due to high bearing pressures is not as large as with a tight belt.

Fig. 202.—Side View of the Eagle Motorcycle Employing Single Chain Drive.

In order to use the chains successfully, the conditions under which they work to the best advantage must be fully realized. The removal of belt pulleys and the substitution of sprockets, and the use of a chain instead of a belt, does not mean that satisfactory chain drive will be obtained. On the contrary, essential conditions peculiar to chain drive must be properly taken into account. First, the nature of the load must be understood. The action of the four-cycle internal combustion engine consists of a series of power strokes due to the explosion of gases which are interposed between periods of neutral or even negative effort While the explosion forces the piston violently downward, during the other three strokes and especially on the com-

pression stroke, the resistance is exactly reversed. A load of this nature is generally known as "impulsive," and is much more severe on the transmission system than the regular turning moment of an electric motor or the smooth action of a four-cylinder gasoline power plant. Consequently, if the chain drive is to be a thorough success, the shocks due to uneven power application must be reduced or absorbed as far as possible by some cushioning mechanism. Another thing that must be taken into consideration is that the speed of a motorcycle engine is very high, and, consequently, the chain speed is correspondingly fast. This is especially true of the first reduction or countershaft drive chain.

It is not generally realized that chain must travel at a velocity of 1,500 to 3,000 feet per minute, and that the impact between the rollers of the chain and the teeth of the sprockets is very severe and frequent. It is therefore important that the chains be kept thoroughly lubricated so the blows on the rollers may be softened by the interposition of a film of lubricant both on the outside of the roller—which is best attained by the use of an oil-bath gear case—and in the bush and rivet bearings. That the roller should be free to turn is also most important, since the wear is thereby distributed.

In view of this last consideration, it is very necessary to make sure that the sprockets are in perfect alinement. Otherwise, the teeth cut into the side plates of the chain, on which they wear a shoulder or ridge, which often causes the rollers to stick, with the result that the impact on the roller always comes in the same place, tending to break it. Correct adjustment also is of course necessary, as, if the chain is too slack, it tends to mount the wheel teeth and also "whips," which may have the effect of breaking the rollers, and in any case, intensifies the wear. The provision of a gear case, or at least some form of chain-guard, is highly desirable. Mud is not a satisfactory lubricant, and it is hopeless to expect the best results from a chain which is coated inside and out with slush and grit. The natural result is stiff joints, broken rollers, and rapid wear.

A point to be looked to in designing a drive is that the number of links in the chain from engine to countershaft should not be an even multiple of the number of teeth in the engine-shaft sprocket, as if this is the case the force of the explosion comes more often on certain

rollers than on the rest. To sum up, the three essentials to be looked for in a motorcycle drive are: First, some species of slipping or cushioning device; second, efficient and thorough lubrication, and third, a reasonable chain speed.

On this last point, a compromise has to be aimed at. The chain speed may be reduced by reducing the diameter of the sprockets, i. e., the number of teeth. But, other things being equal, a small sprocket is more severe on the chain than a larger one, owing to the increased angle at which the wheel meets the chain. Normally speaking, the best results will be attained with driver or engine-shaft sprockets having from 15 to 17 teeth.

Single Chain Drive.—The simplest form of chain transmission and the most efficient is the single chain drive which, to date, has not been extensively applied in motorcycle practice. The method of using a single chain is clearly outlined at Fig. 202. This involves the use of an engine-shaft clutch, which also acts as a cushioning device, from which the drive is to a large sprocket mounted on the rear wheel hub. In the machine shown, the rear sprocket has 64 teeth and the engine sprocket from 16 to 18 teeth. The system of transmission is efficient, and about the only disadvantage that can be advanced against it is that the chain must be kept tight, because if loose it will be apt to flap or whip, owing to its length.

Another method of using a single chain is in combination with an undergeared drive and is outlined at Fig. 203. In this, the first reduction is by a spur pinion attached to the engine crankshaft which meshes with an internal gear that turns the driving sprocket. As practically all of the reduction in speed may be obtained between the gears, the front sprocket may be made nearly as large as the rear one, and the chain is operating under very favorable conditions, as relates to both chain speed and bending. The single-chain direct drive is, of course, the most efficient, as there is no bearing friction other than that of the engine shaft and rear hub to be overcome, while in the countershaft form its bearings consume power.

Double-Chain Drive.—The method of employing two chains for driving, used on the Alcyon (French) motorcycle, is shown at Fig. 204. A small sprocket is attached to a cushioning device carried on the engine shaft, and drives a larger sprocket mounted on a counter-

shaft of the simple form. The drive to the rear wheel is from the small countershaft sprocket to a large member attached to the rear hubs. This provides a double reduction system, there being one reduction in speed between the engine sprocket and the member it drives on the countershaft, and another reduction between the smaller sprocket on the countershaft and the larger member on the hub. The original and as time has proven, the most practical system of double-chain transmission is illustrated at Fig. 205, which shows the transmission method employed on the Indian motorcycle. Even on the earliest forms, a compensating sprocket or cushioning arrangement was used

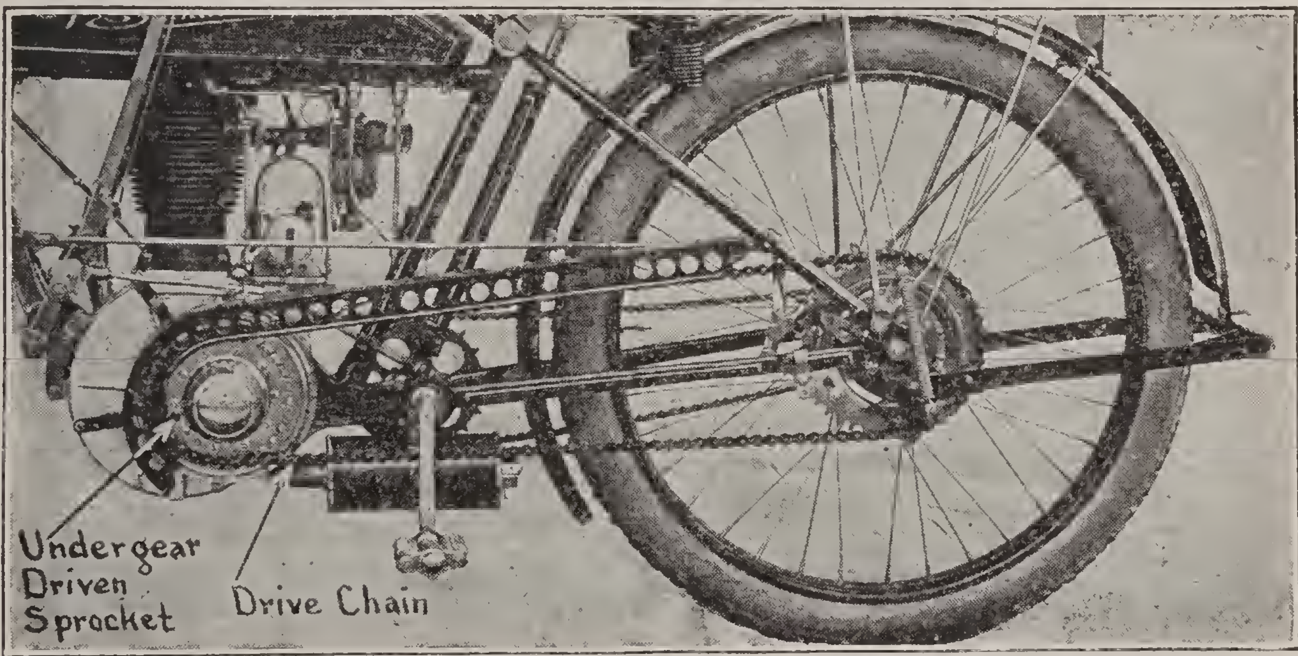


Fig. 203.—Undergeared Single Chain Drive of Reading-Standard Motorcycle.

on the countershaft, but in the modern types it is, of course, unnecessary to use any cushioning device other than the free engine clutch regularly provided on all these machines.

Types of Driving Chains.—The form of driving chain generally used at the present time for power transmission on both motorcycles and automobiles is a radical departure from the type of chain first used for the purpose. In order to reduce friction, and to insure easy running, rollers are used to come in contact with the sprocket teeth, and these roll instead of rub against the teeth as was the case with the block chain. A typical roller chain is shown at Fig. 206, A. Each roller is mounted on a bushing which joins a pair of side plates.

In this form, a link member is composed of two side plates, two bushings to hold them together, and two rolls that revolve on these bushings or hollow rivets. Each of these link assemblies is joined with its neighboring one by a simpler element composed of a pair of side plates and two solid rivets or bolts. The block chain which is shown at C is a simpler construction than the roller chain, as a link assembly is of the more simple form, i. e., two side plates and their retaining rivets is used to join the blocks. That shown at B is a roller chain

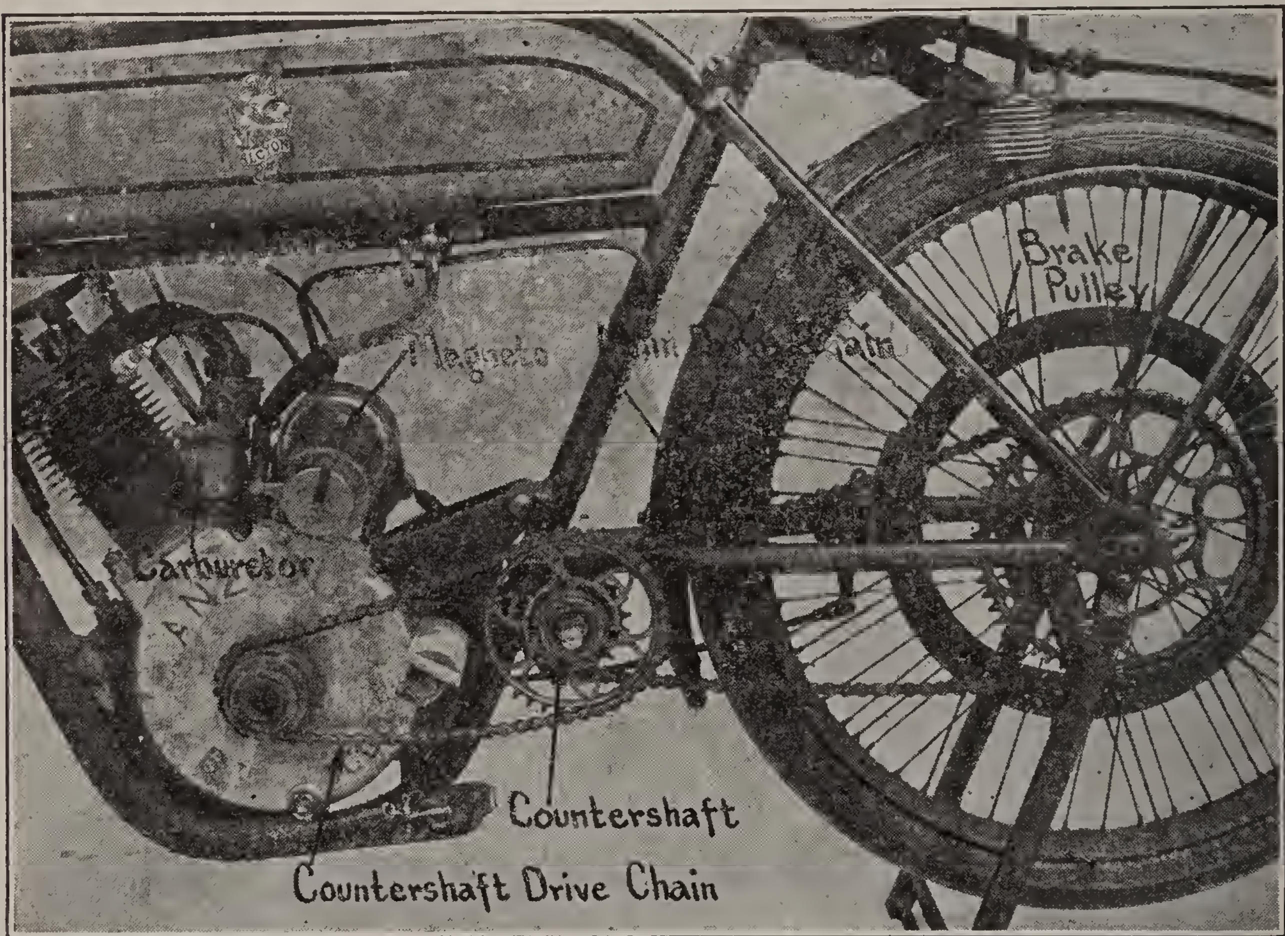


Fig. 204.—Application of Double Chain Drive to Alcyon (French) Motorcycle.

that can be used on block-chain sprockets. Block chains are seldom used for transmitting power at the present time, and when utilized are employed only for joining the pedaling sprocket to the corresponding member on the rear hub, or in connection with a step starter.

The parts of a typical roller chain are clearly shown at Fig. 207. At A, a connecting link which is used for repair purposes or to permit of taking the chain apart when it is necessary to remove it is shown. At B, the connecting link employed to join the roller link members C

is outlined. The offset link at D is used in joining a chain together under conditions where the regular connecting link A cannot be employed, which is the case if the chain has an uneven number of links, such as 63, etc. At the lower portion of Fig. 207, the chain repair tool used for taking riveted chains apart is shown. It consists of a block member which supports a slotted piece having the slots separated by a distance equal to the pitch of the chain to be repaired. A guide member shown at the right can be placed over the head of the rivet which is driven out by means of the punch that is adapted

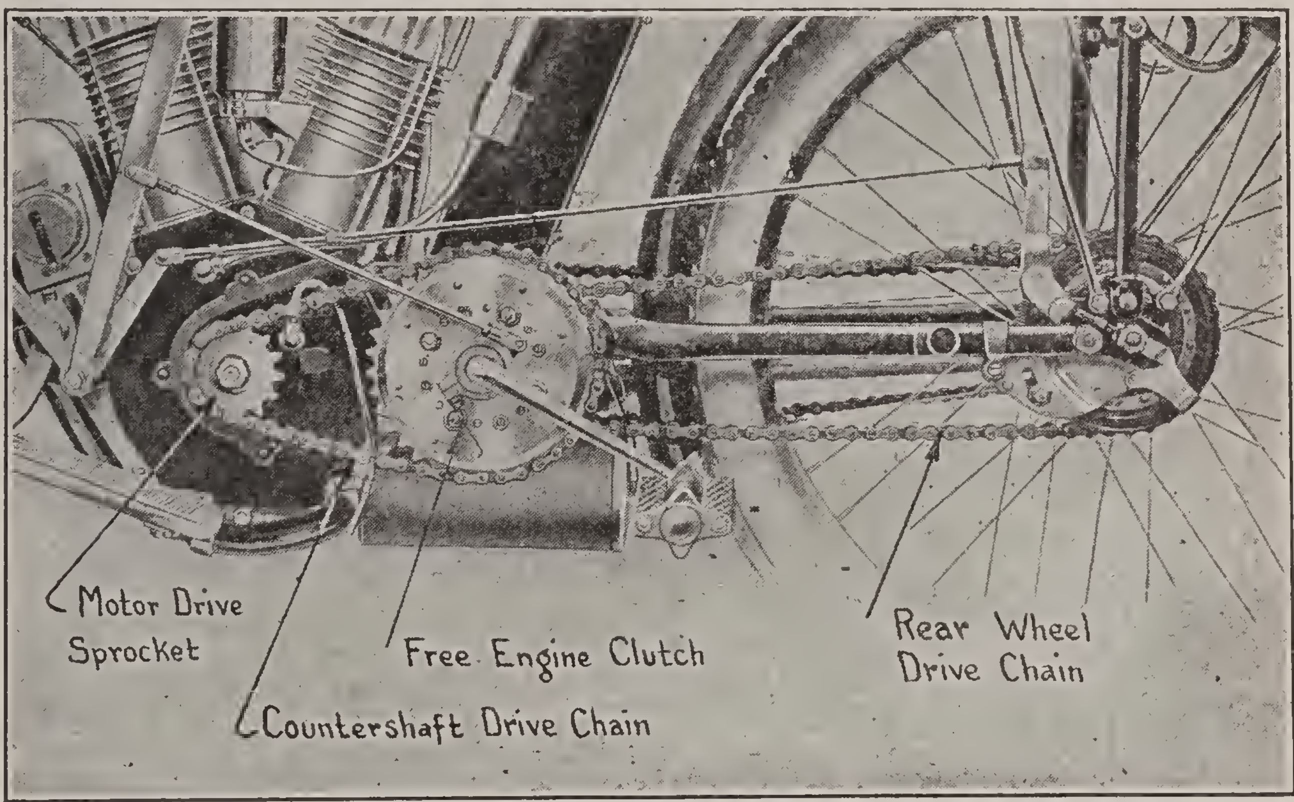


Fig. 205.—Double Chain Drive System Used on Indian Motorcycles on Which Machine This System of Power Transmission Originated.

to fit the guide piece. This arrangement is the only practical method of holding a chain for repairing, as it not only insures that the rollers or links will not be marred but it also provides the firm support that is necessary to drive out the rivets.

The popular motorcycle chain used in this country is a $\frac{5}{8}$-inch pitch with a $\frac{1}{4}$-inch width roll for engines below 5 horse-power, and $\frac{5}{8}$-inch pitch with $\frac{5}{16}$-inch or $\frac{3}{8}$-inch roll for engines of greater power. Two other sizes of chains are being used to some extent, these being $\frac{11}{16}$-inch and $\frac{3}{4}$-inch pitch. The pitch of a chain is the

distance between the center of one tooth space to the center of the neighboring one. In some cases where very low-powered engines are used, chains of ½-inch pitch with $\frac{3}{16}$-inch or ¼-inch wide rolls are sometimes employed. The breaking strain of chains used will range from 2,000 pounds to 3,000 pounds. Considerable useful information, in the form of formulæ for figuring chain length, sprocket sizes, etc., that will be of value to the designer or draftsman, or to the motor-

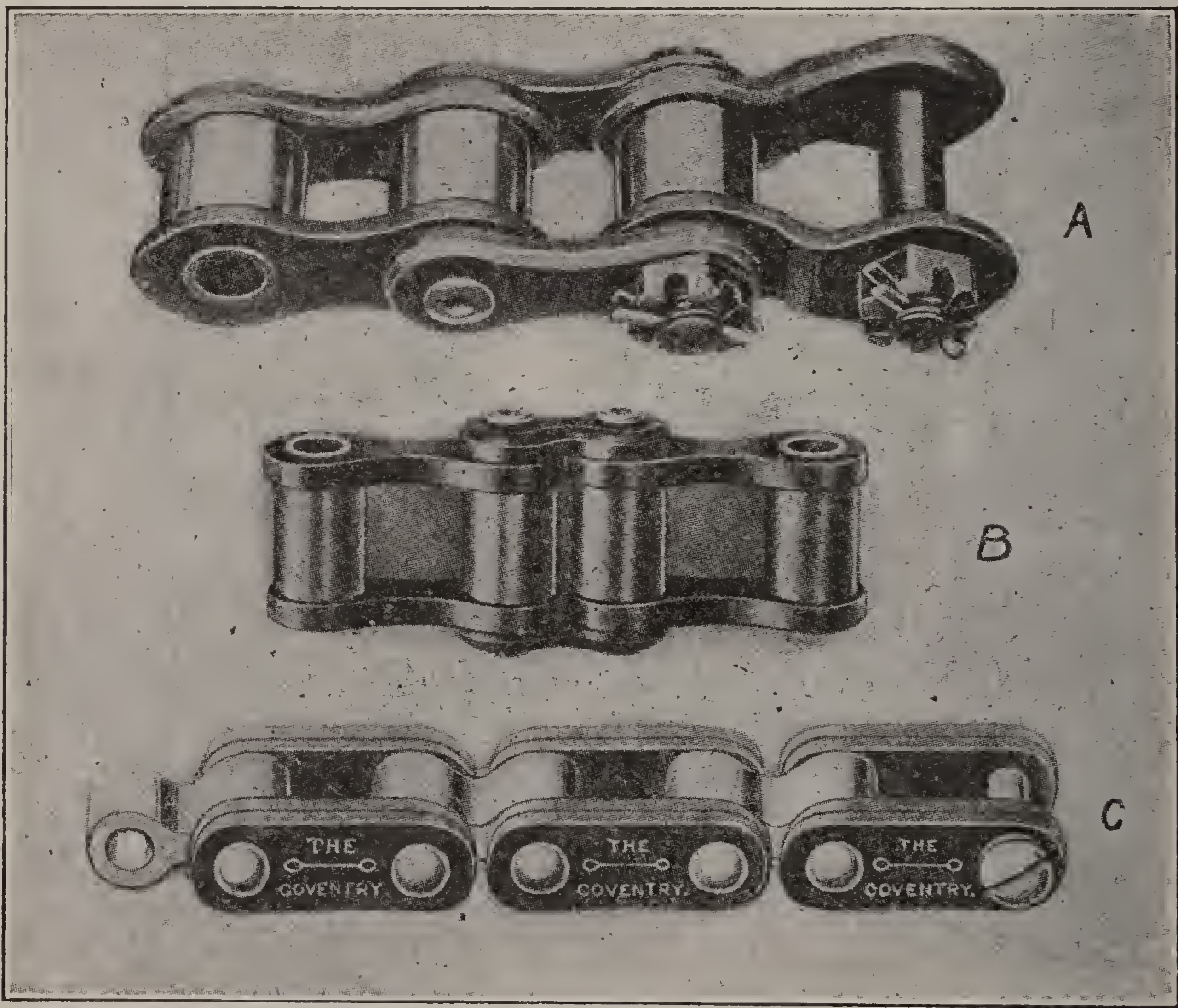


Fig. 206.—Types of Motorcycle Driving Chains.

cyclist who is mechanically inclined, are given in Figs. 208 to 210, inclusive.

Combination Chain and Belt Drive.—In an endeavor to obtain the advantages of both of the main systems of power transmission without the attendant disadvantages incidental to the use of either alone, combination drives are receiving considerable attention at the present time. The average composite drive consists of a chain or

gear drive to a belt pulley, and from that member to a larger belt pulley on the rear wheel. The construction of the usual undergeared drive may be clearly grasped by referring to Fig. 211. While in this case the drive to the rear wheel is by chain, it is not difficult to substitute a belt pulley for the sprocket and drive by the more flexible means. The first reduction is obtained by the spur driving pinion attached to the engine crankshaft which meshes with an internal or ring gear mounted in a suitable extension from the engine base and revolving on ball bearings of generous proportions. The ring gear carries the final drive member.

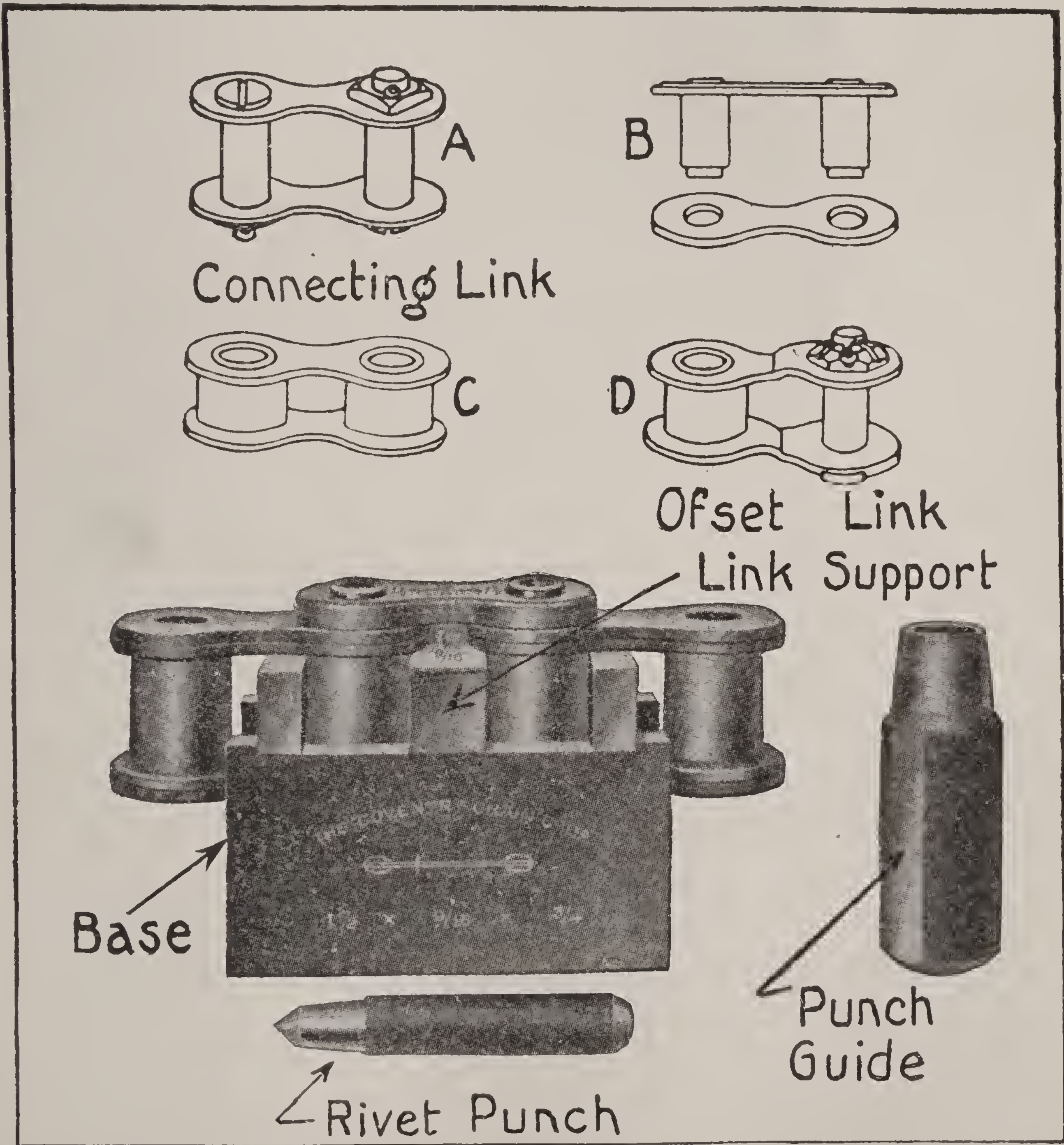
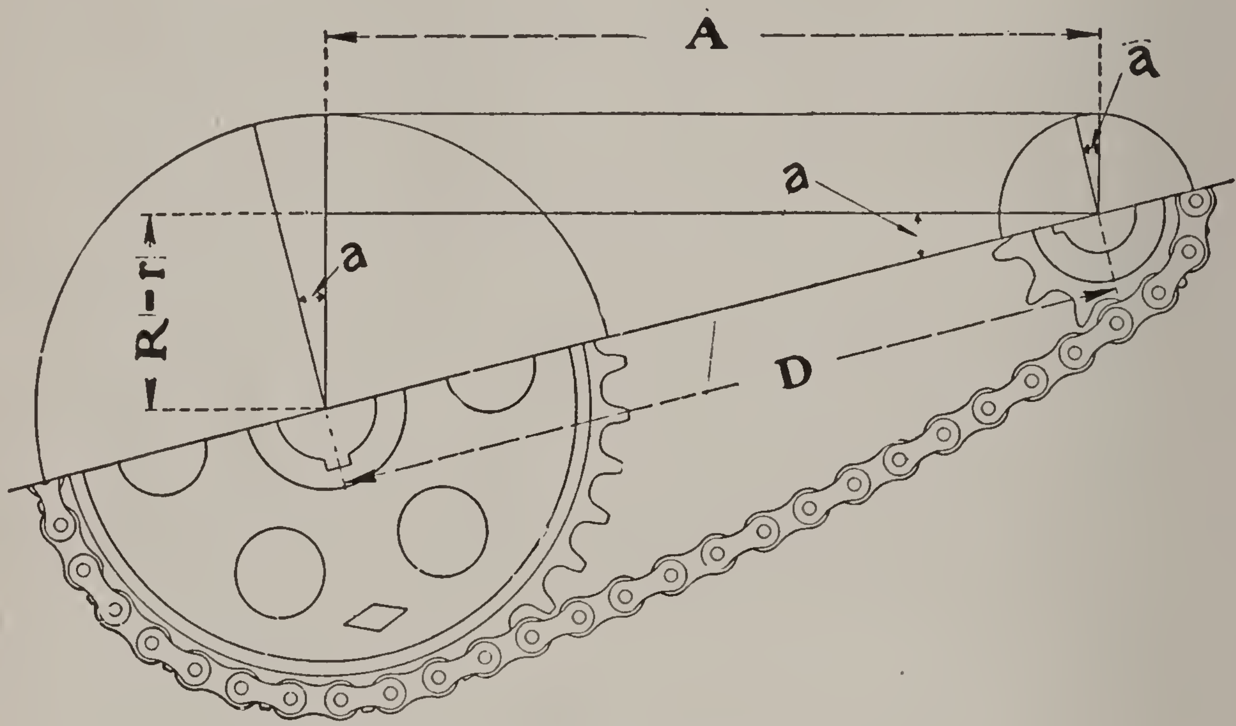


Fig. 207.—Roller Driving Chain Parts and Repair Tools.

For Calculating Length of Chain



(All Dimensions in Inches.)

D = Distance between centers.
A = Distance between limit of contact.
R = Pitch radius of large sprocket.
r = Pitch radius of small sprocket.
N = Number of teeth on large sprocket.
n = Number of teeth on small sprocket.
P = Pitch of chain and sprocket.
$(180^\circ + 2a)$ = Angle of contact — large sprocket.
$(180^\circ - 2a)$ = Angle of contact — small sprocket.

$$a = \sin^{-1} \frac{R-r}{D}$$

$$A = D \cos a$$

Total length of chain.

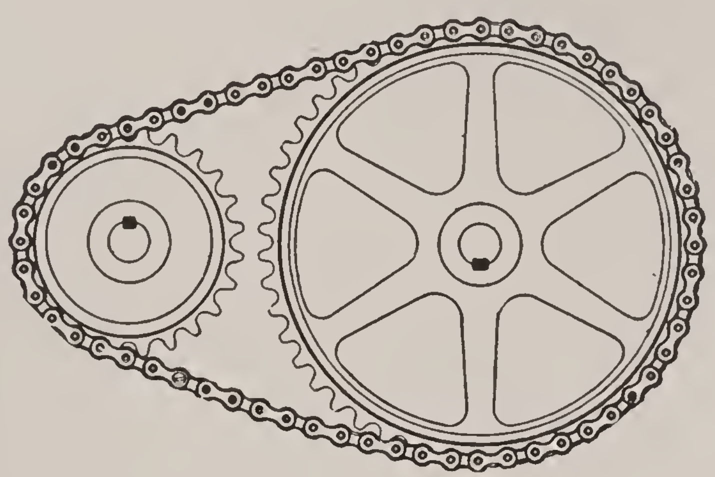
$$L = \frac{180 + 2a}{360} N P + \frac{180 - 2a}{360} n P + 2D \cos a.$$

Fig. 208.—Useful Formulae for Obtaining Length of Driving Chain.

One of the disadvantages incidental to belt drive when used alone was that a small driving pulley which did not provide a sufficiently large contact surface had to be used on the engine shaft to secure the proper gear ratio. With the undergeared drive, which is shown at the top of Fig. 212, or with the combined chain and belt drive outlined at the bottom of the same illustration, it is possible to use a belt pulley of large diameter and obtain an arc of contact that will

Minimum Centres for Chain Wheels

Roller Drive



When ratio is as 1in. is to (3in. + $\frac{P}{4}$ + $\frac{1}{8}$in.) or over, then centres = D − d.
When ratio is less than 1in. is to (3in. + $\frac{P}{4}$ + $\frac{1}{8}$in.) then centres $\frac{D+d+P}{2}$

DATA:

P . . . Pitch of chain wheel in inches.
D . . . Pitch dia. of chain wheel in inches.
d . . . Pitch dia. of pinion wheel in inches.

Fig. 209.—Diagram Showing Calculation for Minimum Centre Distances for Sprockets.

insure positive drive and minimum flexure of the drive belt. The first reduction is obtained by positive means which are best adapted for this purpose, while the final drive is taken by the flexible member which provides the smooth and yielding transmission that is so desirable to relieve the power plant of road shocks. The view at Fig. 213 is that of a representative American motorcycle, the Reading Stand-

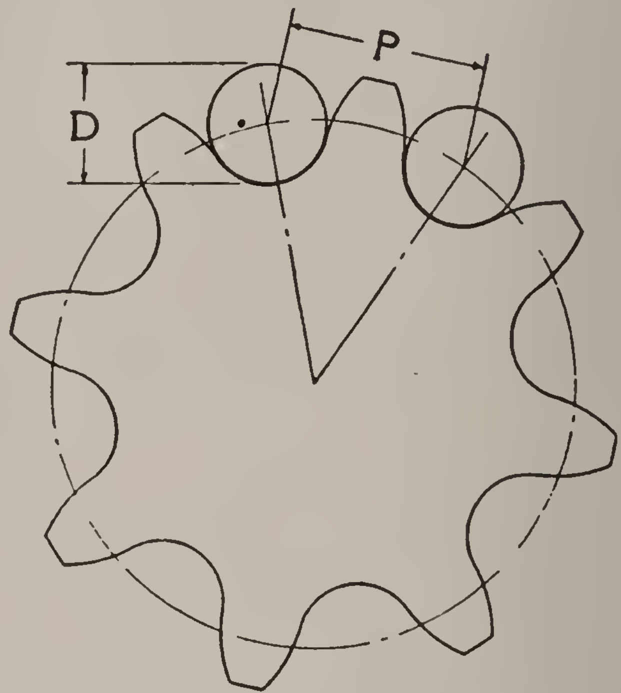
For Calculating Diameters of Sprocket Wheels for Roller and Built-Up Block Chains

N = Number of teeth in sprocket.
P = Pitch of chain.
D = Diameter of roller.

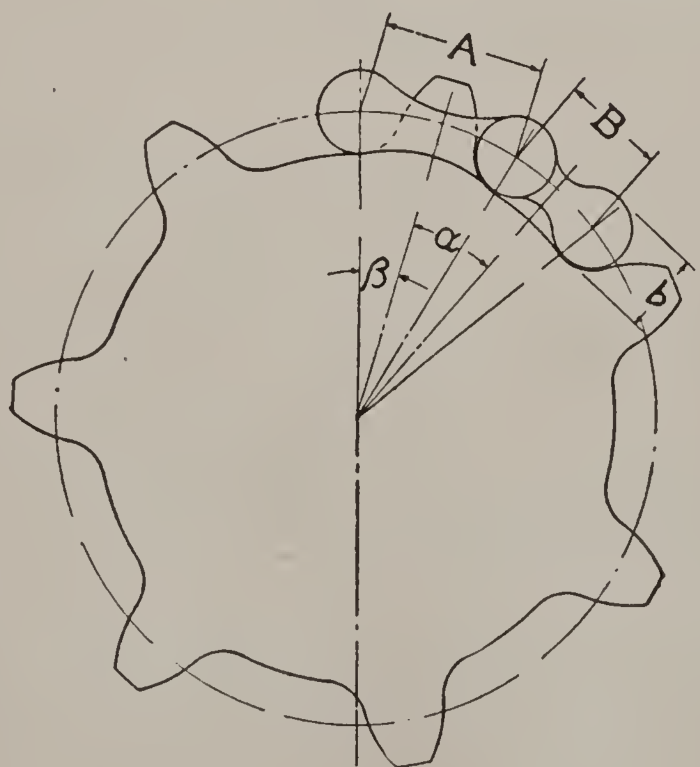
$$a = \frac{180^\circ}{N}$$

$$\text{Pitch Dia.} = \frac{P}{\text{Sin. } a}$$

Outside Diameter = Pitch + D.
Bottom Diameter = Pitch − D.



For Calculating Diameters of Sprocket Wheels for Block Center and Twin-Roller Chains



N = Number of teeth.
b = Diameter of round part of chain block (usually .325)
B = Center to center of holes in chain block (usually .4)
A = Center to center of holes in side links (usually .6)

$$a = \frac{180^\circ}{N}$$

$$\text{Tan. } B = \frac{\text{Sin. } a}{\frac{B}{A} + \text{Cos } a.}$$

$$\text{Pitch Diam.} = \frac{A}{\text{Sin. } B}$$

Outside Dia. = Pitch Dia. + b
Bottom Dia. = Pitch Dia. − b

In calculating the diameter of Sprocket wheels, the bottom diameter is the most important

Fig. 210.—Diagrams Showing Method of Calculating Sprocket Sizes for Roller and Block Chains.

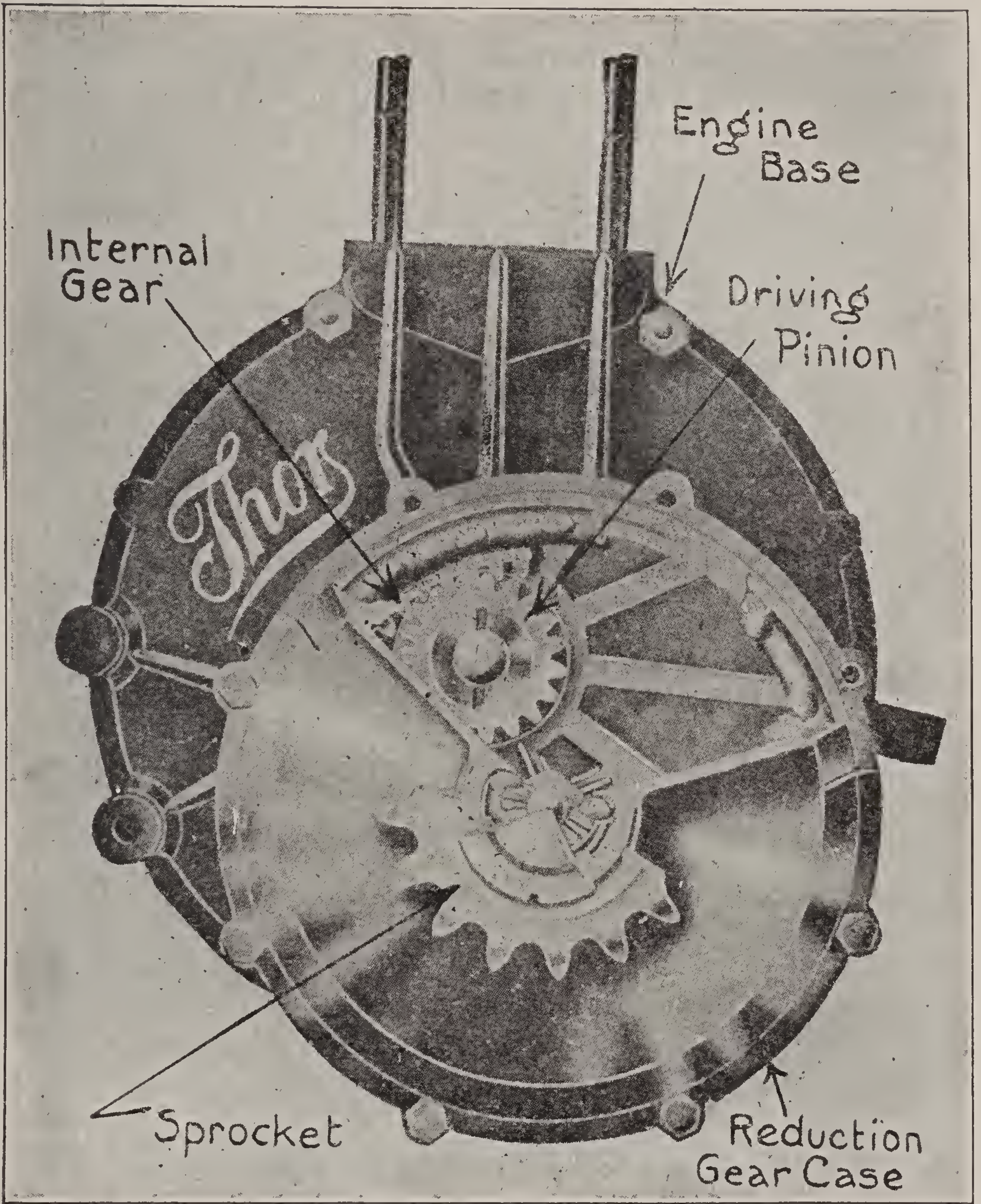


Fig. 211.—Undergeared Drive of Thor Design.

ard, employing the combination undergeared drive. The relative size of the front and rear driving pulleys may be readily ascertained and it is not difficult to understand how a combination drive of this nature is destined to become a very popular system, inasmuch as it will provide a positive drive and yet a flexible one.

Bevel and Worm Gear Final Drive.—The most popular system of driving automobiles is undeniably that in which thoroughly encased gearing is used. The problem of applying this form of gearing to motorcycles is not an easy one to solve, because the construction is difficult to apply. In an automobile, it is not necessary to remove

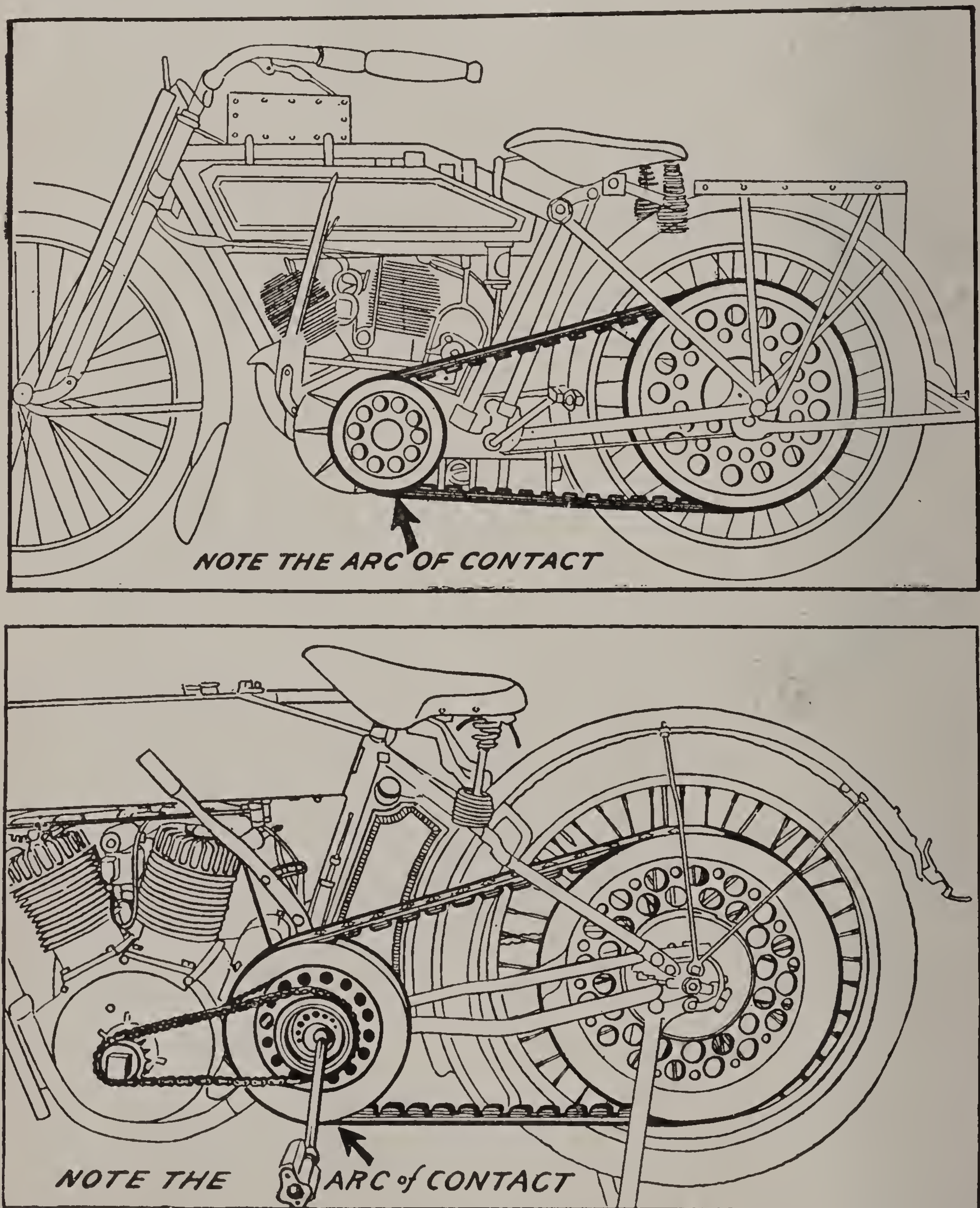


Fig. 212.—Two Methods of Using Belt Transmission in Connection With Positive First Reduction Means.

the rear axle every time a wheel must be reached to make repairs on the tires. In a motorcycle, it is necessary to take the rear wheel out of the frame before one can change a shoe or one-piece inner tube, and, whenever gear drive is used, it is somewhat of a job for an amateur to

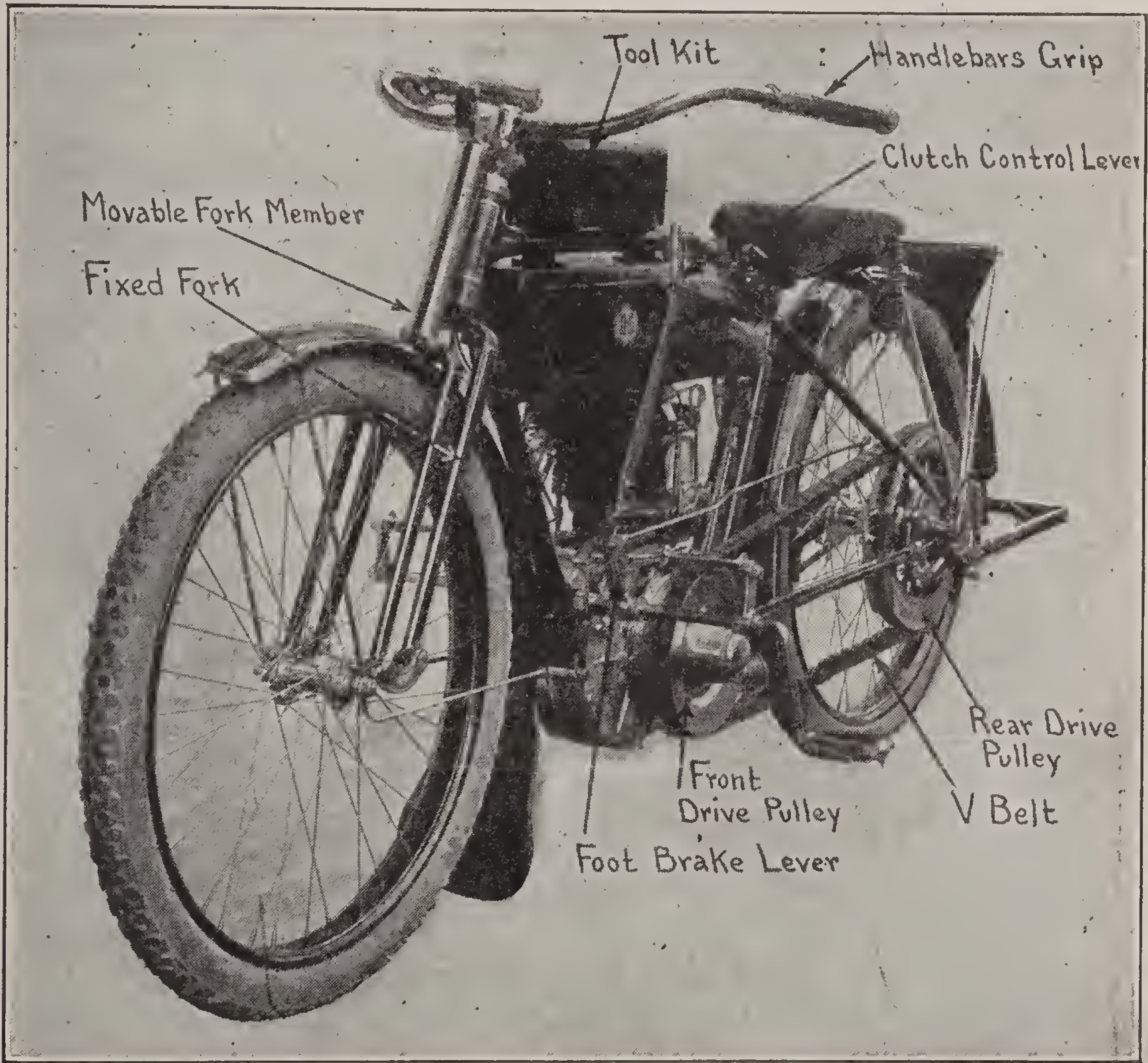


Fig. 213.—Three-Quarter Front View of 1914 Reading-Standard Single Cylinder Model, Showing Application of Undergeared V Belt Drive.

remove the wheel, and more of a proposition to replace it and secure proper adjustment of the drive gearing.

A bevel gear drive which has received successful application on the Pierce four-cylinder motorcycle is shown at Fig. 214. The rear hub member carries a bevel gear in place of the usual drive sprocket, and the power is transmitted to that member by a bevel drive pinion

securely attached to a drive shaft that extends to the motor crankshaft. A worm gear drive used on an English motorcycle is shown at Fig. 215. The system is just the same as that previously described except that worm gearing is used instead of the bevel, for with either of these forms it is necessary to mount the engine in the frame in such a way that the crankshaft is parallel to the top frame tube.

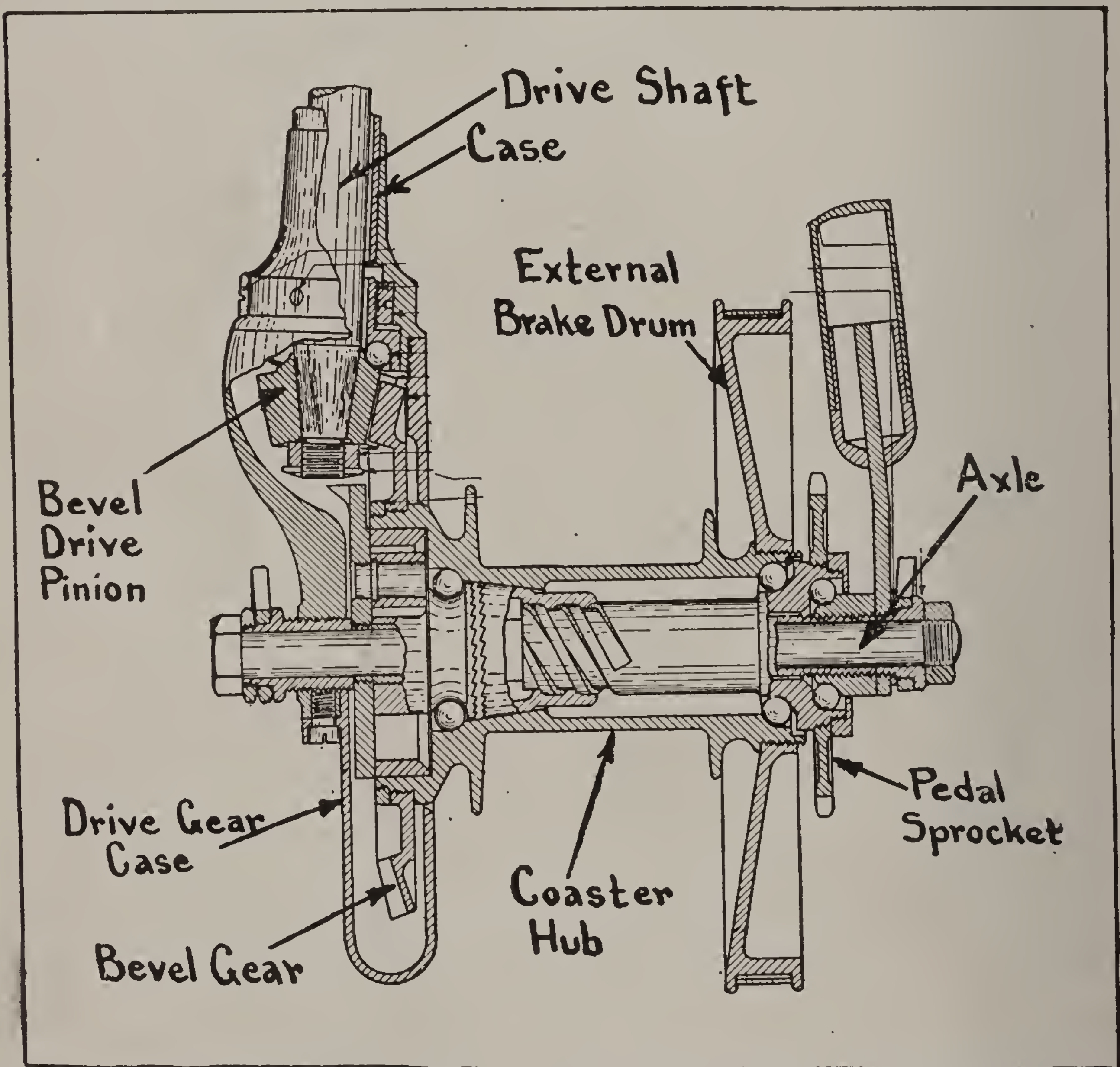


Fig. 214.—Bevel Gear Driving System of Pierce Four Cylinder Motorcycle.

The power transmission of the Fielbach motorcycle at Fig. 216 is distinctive, inasmuch as the twin-cylinder power plant is mounted in the frame in the conventional manner with its crankshaft at right angles to the frame tubes. The drive is by spiral gearing at the engine through a cone clutch and sliding gear transmission of the two-speed type to a worm gear carried on the rear axle. The view at the top

shows the relation of the engine gearing, the clutch and the change-speed gearset. The drive from the gearset-driven shaft is to a worm mounted in a suitable casing which is shown in the longitudinal section in the lower left hand corner. The method of fastening the worm gear to the wheel hub is clearly outlined in the right hand corner. This system of gearing is more complicated and much more expensive to construct than the simpler two-chain or combination chain and

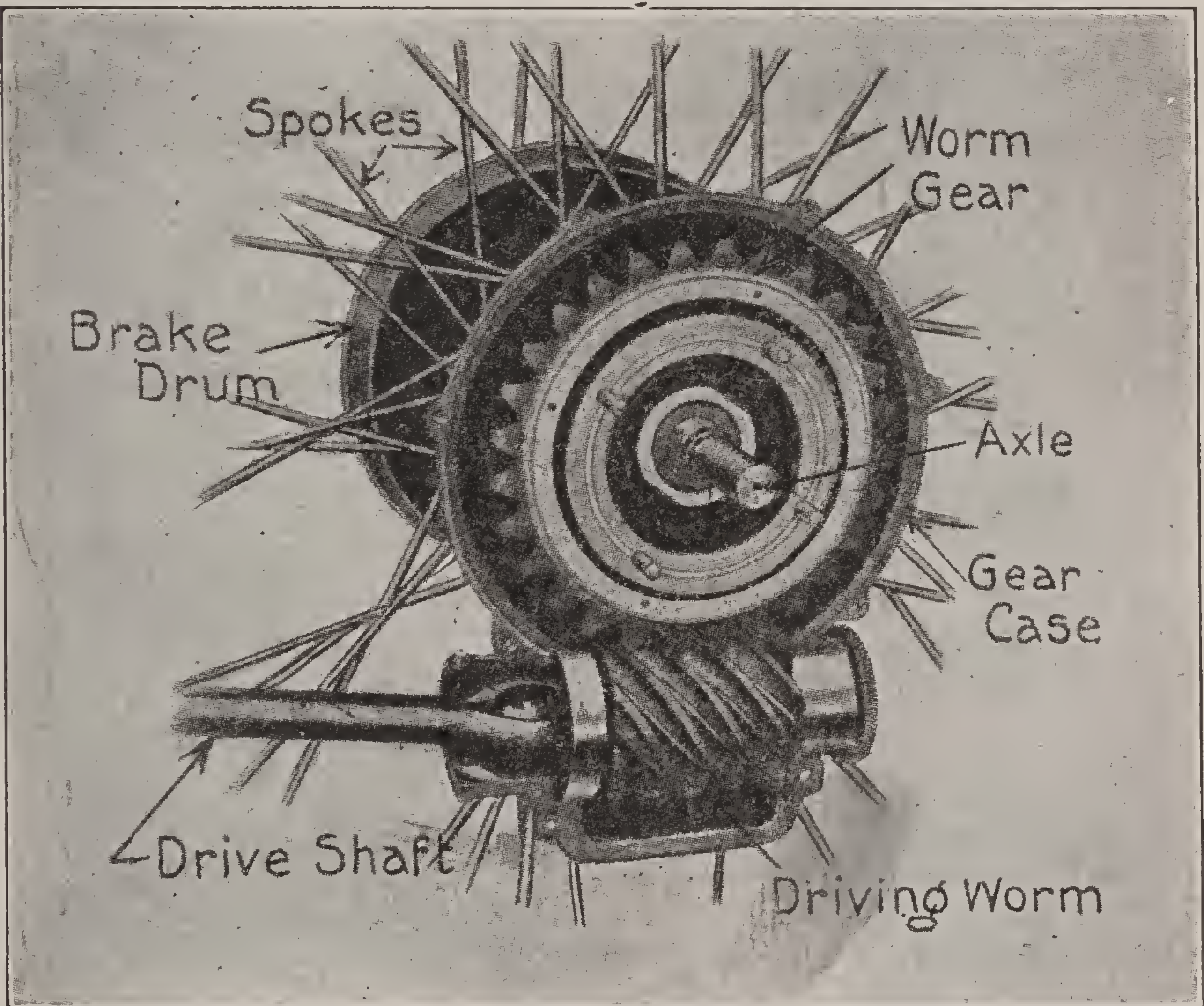


Fig. 215.—Worm Drive System of T. A. C. (English) Four Cylinder Motorcycle.

belt drive, but it has the important advantage of having all the driving elements thoroughly encased and protected from the abrasive effect of road grit, which cannot be said of any of the chain or belt drive systems. An important advantage of the positive encased gear drive is that the housings in which the gears are mounted may be filled with lubricant, and this not only cushions and silences the drive but it also reduces friction and wear, and promotes long life of the driving

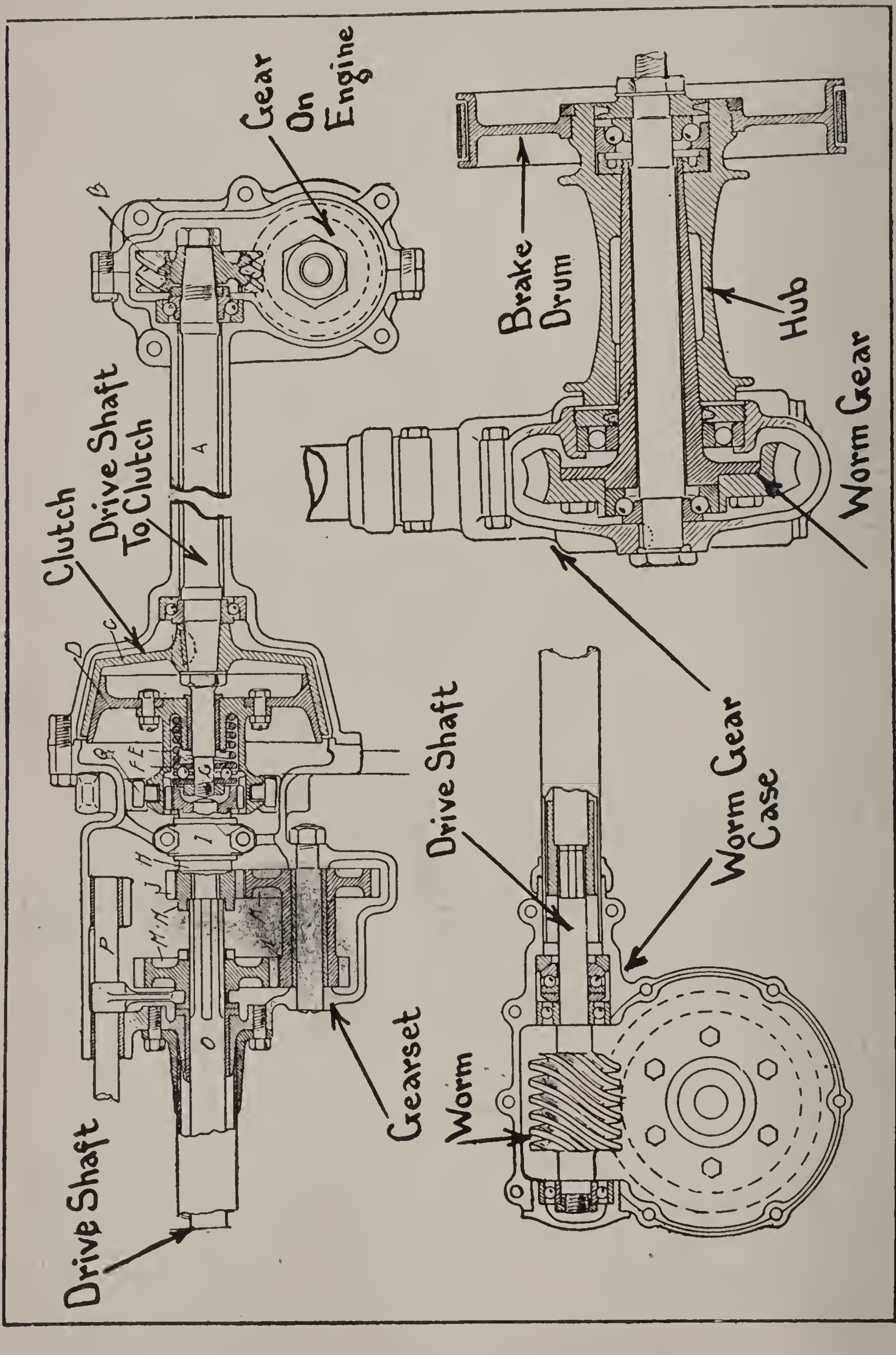


Fig. 216.—Application of Worm Drive System on the Fielbach Motorcycle.

Relation of Engine Power to Gear Ratio.—In one of the earlier chapters the reason for supplying various gear ratios has been considered in some detail, and the importance of selecting that best adapted so the power of the engine will be delivered most effectively is an important phase of motorcycle design. An engine may be geared too high, which means that it will have some difficulty in overcoming the resistance imposed by hills or bad roads but is very fast on the level. If a machine is geared too low, it will be a good hill climber but will not operate at satisfactory speeds under good conditions unless the engine is run excessively fast, which would produce more rapid depreciation of the power plant.

The two tables appended are given to show the gear ratios recommended by engine builders for their different motor types. It is, of course, understood that the designer of the motorcycle will select the power plant of the proper capacity for the machine to which it is fitted. The first table is given by the makers of the Precision (English) engines, various models of which have been illustrated in this work. The last table is especially valuable, as it shows not only the gear ratios but the road speeds obtained with various sprocket sizes and single and twin engines. This table has been compiled by the F. W. Spacke Machine Company who make the De Luxe motors. Other tables and formulæ to assist in figuring speed are also presented.

Riders will do well to remember that cycle engines are essentially high-speed engines, and should not be over-geared. The following table will be found to give best results both from the point of view of flexibility and average speed:

Engine Type.	Gear Ratio for Solo Riding.	Gear Ratio for Sidecars, Top Gear.
2½ horse-power	5½ to 1	....
2¾ horse-power	5 to 1	....
3¾ horse-power	4½ to 1	5½ to 1
3¾ overhead valves	4 to 1	5 to 1
4 horse-power twin	4½ to 1	5 to 1
Green model	4 to 1	5 to 1
4¼ horse-power	4½ to 1	5 to 1
6 and 8 horse-power twin models	4 to 1	4½ to 1

TABLE OF SPROCKET SIZES, GEAR RATIOS AND MOTORCYCLE SPEEDS FOR USE WITH DE LUXE ENGINES.

Size of Motor.	Motor Sprocket Number Teeth.	Eclipse Countershaft Sprockets.	Hub Sprocket Number Teeth.	Gear Ratio.	Speed with Motor Running 2,500 R.P.M. Miles per Hour.
4 and 5 horse-power singles	12	33 and 17	27	4.37 to 1	47.7
	12	33 and 17	29	4.69 to 1	44.4
	12	33 and 17	31	5.01 to 1	41.5
	12	33 and 17	35	5.66 to 1	36.8
7 and 9 horse-power twins	14	33 and 17	23	3.19 to 1	65.3
	14	33 and 17	25	3.47 to 1	60.1
	14	33 and 17	27	3.75 to 1	55.6
	14	33 and 17	29	4.02 to 1	51.8
	14	33 and 17	31	4.30 to 1	48.4

The point of highest efficiency and horse-power development is represented at approximately 2,500 revolutions per minute, on standard stock motors, and is, for that reason, taken as a basis for estimating gear ratios. The above does not, therefore, necessarily represent the extreme maximum of speed that may be obtained from any gear ratio.

SPEED FORMULA.

To reduce A miles in B seconds to miles per hour,

$$A \times \frac{3{,}600}{B} = \text{miles per hour.}$$

SPEED EQUIVALENTS IN AMERICAN AND FRENCH MEASUREMENTS.

1 mile per hour	= 88	feet per minute.
	= 1.46	feet per second.
	= 27.8	meters per minute.
	= 0.463	meter per second.
1 kilometer per hour	= 0.624	miles per hour.
	= 54.9	feet per minute.
	= 0.914	meter per second.

RATE OF SPEED IN MILES PER HOUR FOR ELAPSED TIME OVER THE MEASURED MILE FROM ONE TO THREE MINUTES.

Time Over Measured Mile.		Rate of Speed in Miles per Hour.	Time Over Measured Mile.		Rate of Speed in Miles per Hour.	Time Over Measured Mile.		Rate of Speed in Miles per Hour.
Min.	Sec.		Min.	Sec.		Min.	Sec.	
1	0	60.00	1	27	41.38	1	54	31.58
1	1	59.00	1	28	40.91	1	55	31.30
1	2	58.06	1	29	40.45	1	56	31.03
1	3	57.14	1	30	40.00	1	57	30.77
1	4	56.25	1	31	39.56	1	58	30.50
1	5	55.38	1	32	39.13	1	59	30.25
1	6	54.54	1	33	38.71	2	0	30.00
1	7	53.73	1	34	38.29	2	3	29.26
1	8	52.94	1	35	37.89	2	6	28.57
1	9	52.17	1	36	37.50	2	9	27.90
1	10	51.42	1	37	37.11	2	12	27.27
1	11	50.70	1	38	36.73	2	15	26.66
1	12	50.00	1	39	36.36	2	18	26.08
1	13	49.31	1	40	36.00	2	21	25.53
1	14	48.65	1	41	35.64	2	24	25.00
1	15	48.00	1	42	35.29	2	27	24.49
1	16	47.37	1	43	34.95	2	30	24.00
1	17	46.75	1	44	34.61	2	33	23.53
1	18	46.15	1	45	34.28	2	36	23.07
1	19	45.57	1	46	33.96	2	39	22.64
1	20	45.00	1	47	33.64	2	42	22.22
1	21	44.44	1	48	33.33	2	45	21.81
1	22	43.90	1	49	33.03	2	48	21.42
1	23	43.37	1	50	32.72	2	51	21.05
1	24	42.85	1	51	32.43	2	54	20.69
1	25	42.35	1	52	32.14	3	0	20.00
1	26	41.86	1	53	31.86	..	..	.....

CHAPTER VI.

DESIGN AND CONSTRUCTION OF FRAME PARTS.

The Motorcycle Frame Structure—Foot-Boards—Rear Wheel Stands—Spring Forks—Spring Supported Seat-Posts—Spring Frames—Saddles and Tandem Attachments—Coasting and Braking Hubs, Why Used—Requirements of Pedal Drive Mechanism—What Brakes Should Do—Force Needed at Brake—Principle of Brake Action—Friction Co-efficient and Its Relation to Brake Design—Leading Types of Brakes—Operation of Typical Braking and Coasting Hub—How Rider's Effort is Multiplied—Motorcycle Tires—Side Car Advantages—Forms of Side Cars—Side Car Attachment and Control—Methods of Starting Motorcycles—Indian Electric Starting and Lighting System—Motorcycle Control Methods—Bowden Wire Control.

We have discussed at some length, in a previous chapter, the various forms of motorcycle frames and methods of power plant support in a general way. In view of the important functions of the frame structure, it may be well to describe this important component upon which the strength and endurance of the entire assembly depends more completely. A typical loop frame, such as used on the Indian motorcycle is shown at Fig. 217, and this shows clearly all of the parts, with the exception of the wheels and handle-bars that are generally considered as being part of the frame assembly.

It will be observed that in certain essential respects this frame differs materially from those used in bicycle construction. The looped member that supports the motor, the drop at the seat-post mast, and the elimination of the usual diamond construction at the rear end are all radical departures from bicycle frame design. In this construction, the effort is made not only to suspend the weight of the rider by resilient members other than pneumatic tires but by the use of the laminated leaf spring fork and the distinctive double cradle spring rear construction, the entire weight of the power plant and its auxiliaries as well as the rider are spring supported and protected from

the undesirable influences of road shock. The complete frame assembly consists of the main frame member to which are attached the front fork at the steering head, a saddle over the seat-post tube, a luggage carrier, chain-guard, mud-guard, and suitable stand at the rear end.

The frame shown at Fig. 218 is representative of the form of construction in which the motor base is depended on to join the open portion of the frame when the power plant is in place. The important parts of this assembly are also clearly outlined. The frame

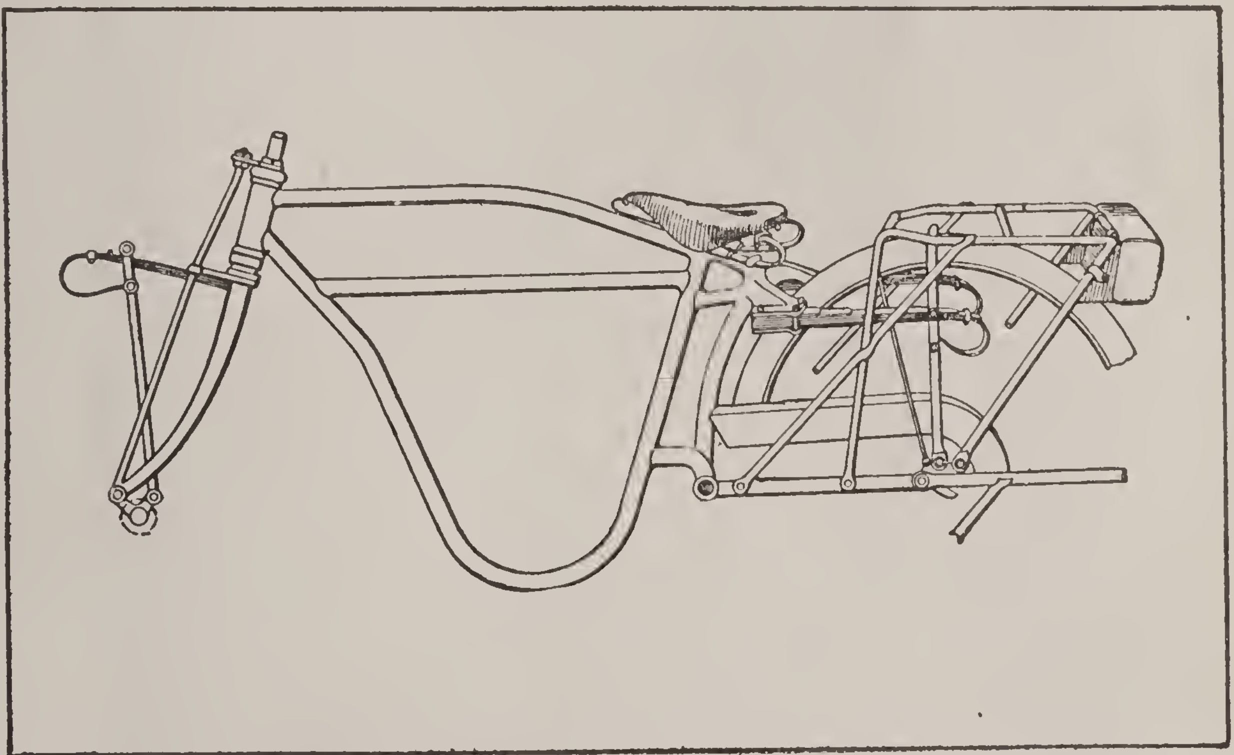


Fig. 217.—Complete Frame Structure of Indian Motorcycle.

at Fig. 219 is a loop design of merit, and shows the complete frame assembly minus the rear wheel. The motor supports are brazed to the frame loop and are in the form of brackets to which the lugs attached to the engine base are bolted. Attention is directed to the distinctive method of strengthening the rear end by means of vertical brace tubes that join the rear forks and rear-fork stays together. The form of the mud-guards, the design of the saddle and handle-bars, and the method of housing the tool compartment under the saddle, in the space between the seat-post mast and the rear mud-guards are also clearly depicted. Another open frame is shown at Fig. 220. This differs from that previously described, in that the motor casing is

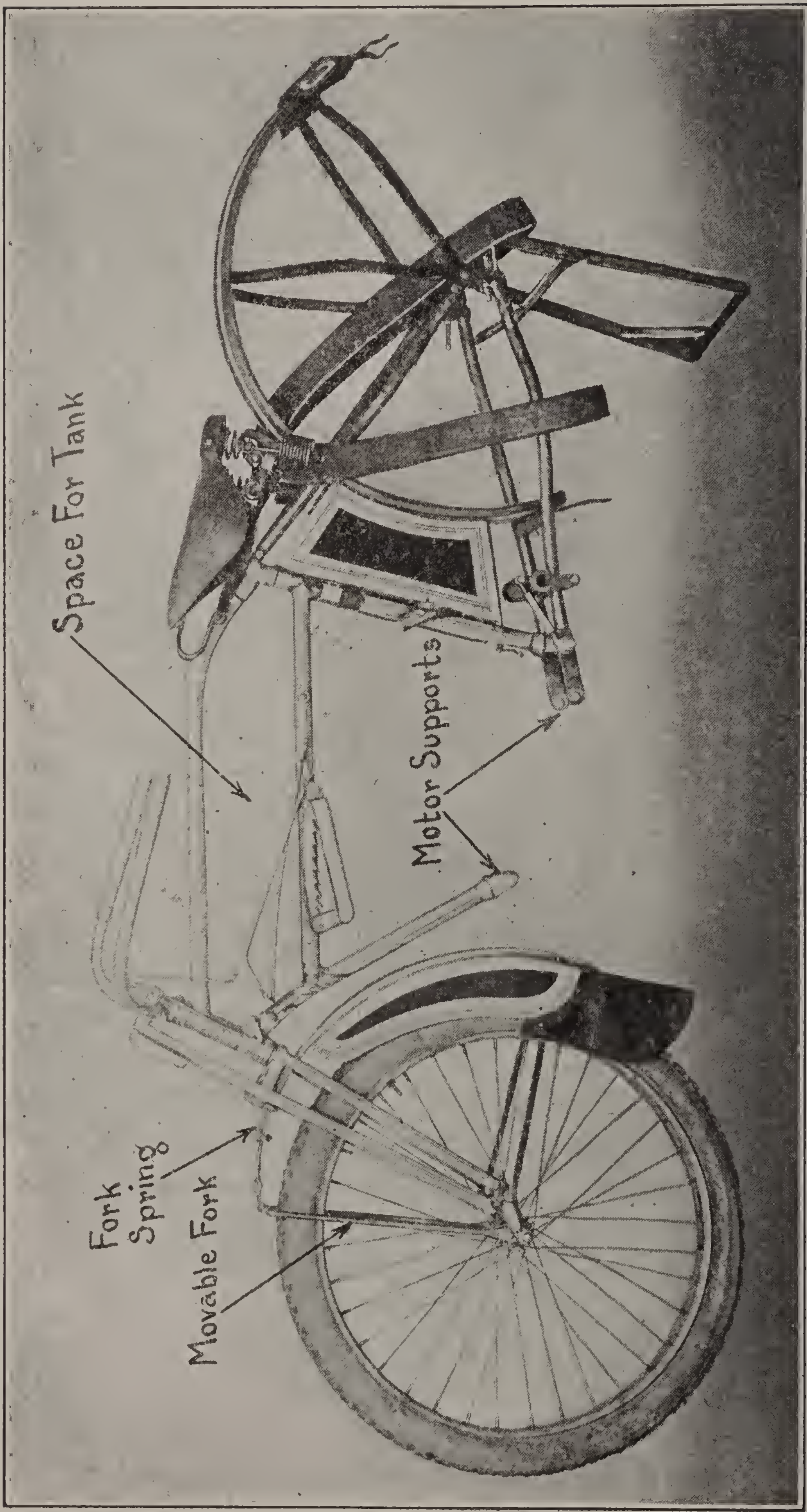


Fig. 218.—Frame of 1912 Eagle Motorcycle Showing Opening Left When Power Plant is Removed.

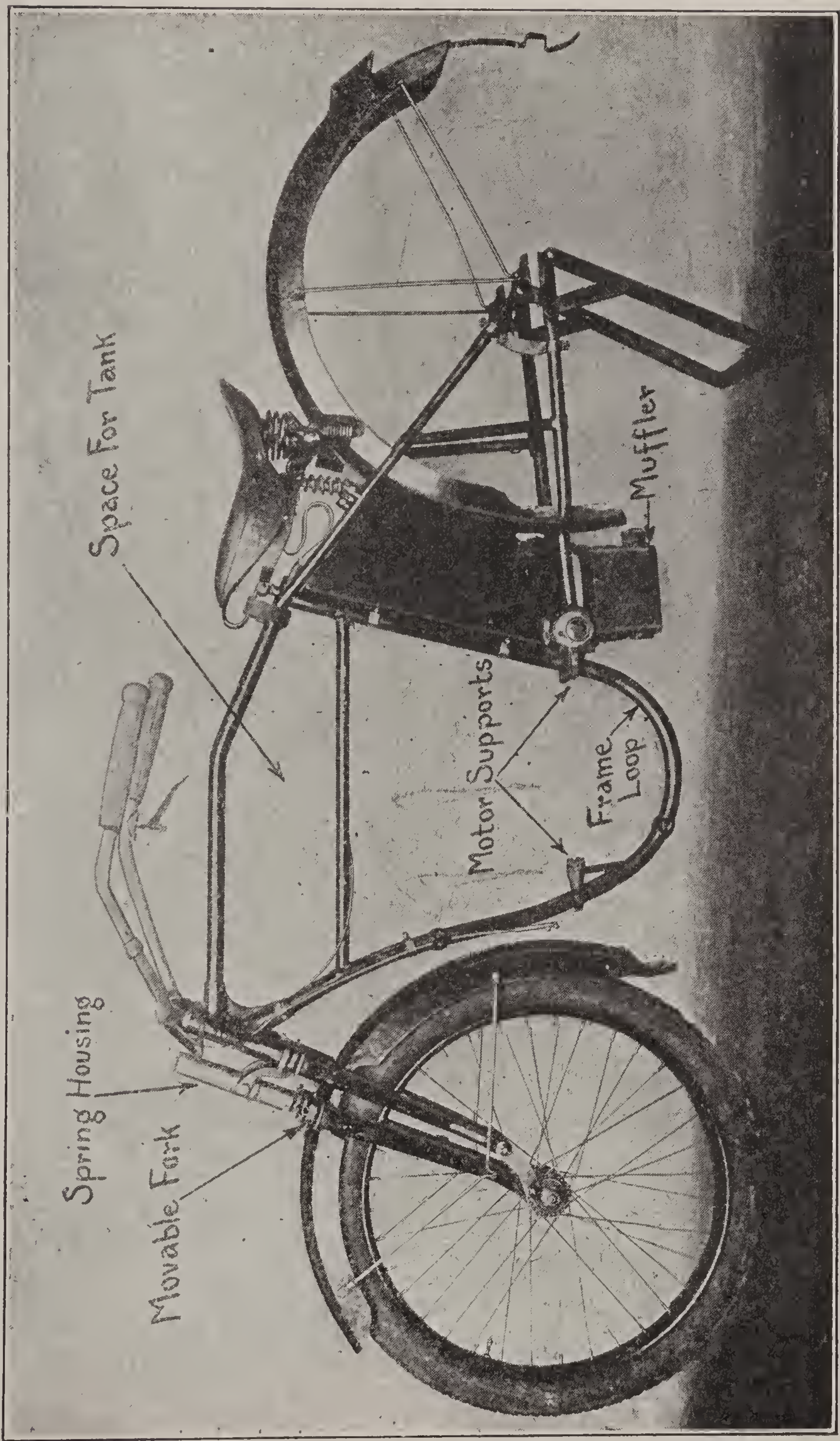


Fig. 219.—The Emblem Loop Frame With Reinforced Rear Construction.

secured to an extension of the crank-hanger by two bolts, and to the end of the diagonal tube with one bolt. Both of these members are forked so it is a simple matter to remove the power plant from the frame when necessary.

A motorcycle frame is generally built up of seamless steel tubing, though some designs have been evolved in which a portion of the frame is composed of a casting member to which the tubes were attached. The frames illustrated at Figs. 217 to 220 are of the pattern in which the various fittings are joined together by steel tubes. The Schickel frame which is depicted at Fig. 221 is a distinctive construction be-

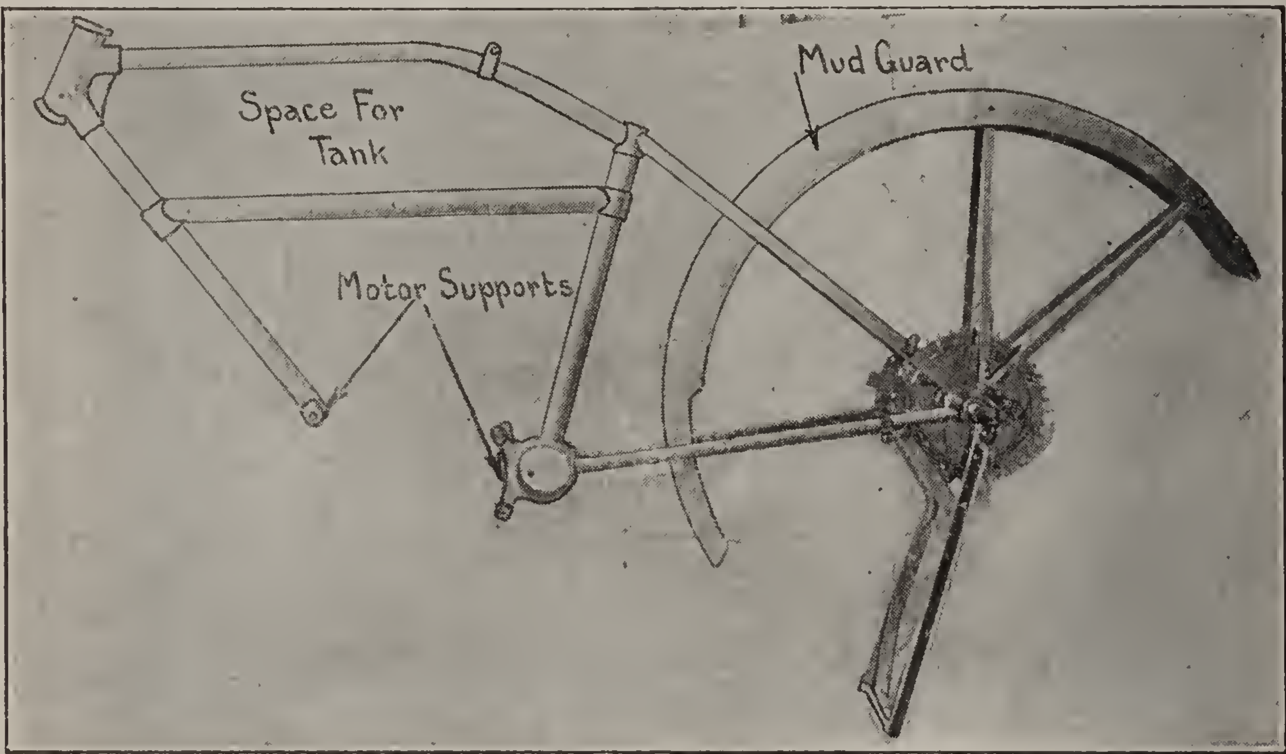


Fig. 220.—Frame of Excelsior Motorcycle Showing Motor Supports.

cause the main portion of the frame is a large aluminum casting which serves as a fuel container. The steering head and a portion of the seat-post tube retaining member are formed integrally with it. Another suitable projecting boss is employed to support the front diagonal tube. The rear fork assembly is built of tubing in the conventional manner. The Pierce motorcycle employs a frame made of large diameter tubing, which members also serve as fuel and oil containers, and which provide a frame of exceptional strength though unconventional in appearance.

When motorcycles were first made, light steel stamped reinforce-

ments of the form used in bicycle frame construction were widely employed to hold the various parts of the motorcycle frame together. At the present time, stampings have been discarded for more substantial drop forgings and malleable iron castings. The steering head of practically all motorcycles is in the form of a forging or semi-steel casting provided with a substantial rib joining the two bosses to which the frame tubes are brazed. The seat-post cluster is also a forging and has four projecting bosses. One of these is intended to secure the seat-post tube, the one at the front is for attaching the upper frame member while the two at the rear form an anchorage for

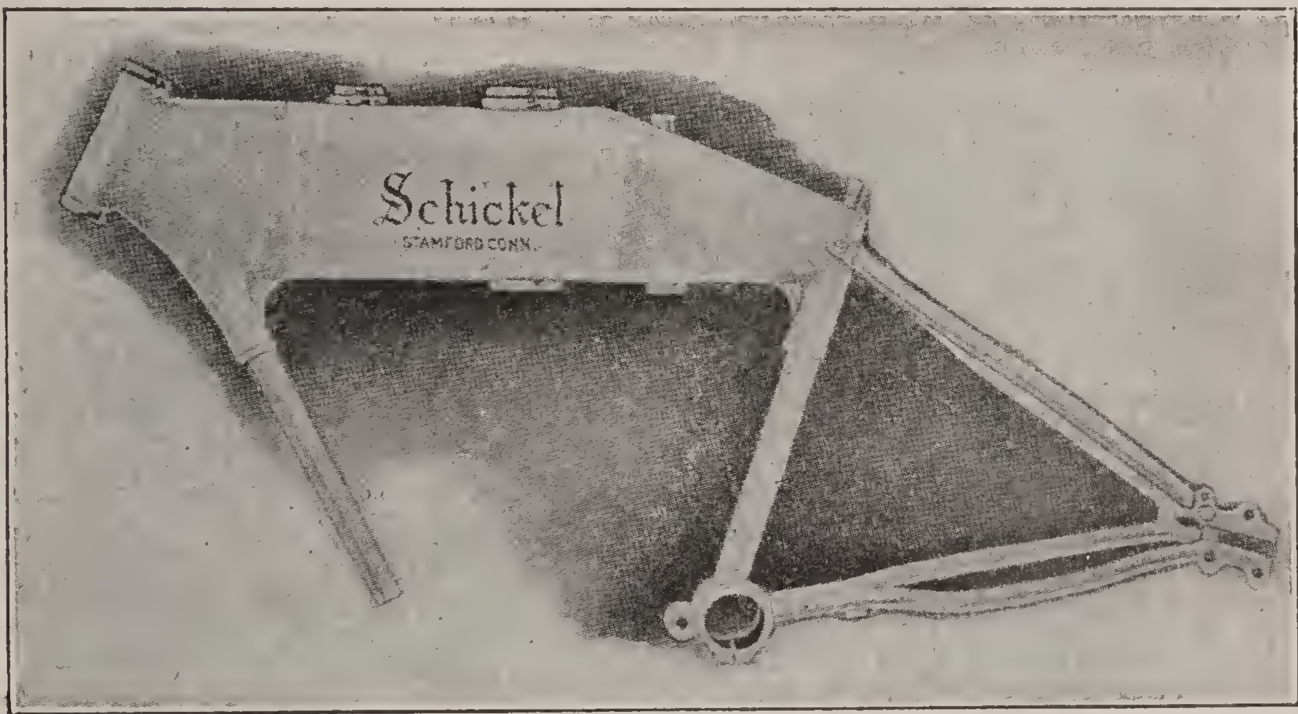


Fig. 221.—The Schickel Frame Construction.

the rear-fork tubes. The crank-hanger is still another member which varies according to the design of the frame to which it is fitted. The two common methods of brazing the frame tubes employed differ in one essential. The fittings are joined to the tubing in some frames by being pushed in the interior of the tube. This makes what is known as a flush joint because no evidence of the point of juncture between the frame and the fitting is noticed. The steering head forging of the Indian motorcycle, which is shown at Fig. 222 has internal reinforcement or flush joints, while the steering head fitting of the frame shown at Figs. 219 and 220 is attached by inserting the tube inside of projecting bosses that form part of the fitting. This method is

often combined with an internal reinforcement and is said to be stronger, though not so neat in appearance, than the flush joint frame construction. The latter has survived from bicycle practice where it was desirable to eliminate all corners in which dirt or dust could collect, and also to have a smooth or finished appearance for the frame. In a motorcycle, the factor of strength is the most important consideration so that externally reinforced joints are used fully as much as the flush joint construction. The tubing used in motorcycle construction is not only of heavy gauge and of large diameter but is invariably provided with an internal reinforcement which in most cases is a vertical steel piece running through the center of the tube. This

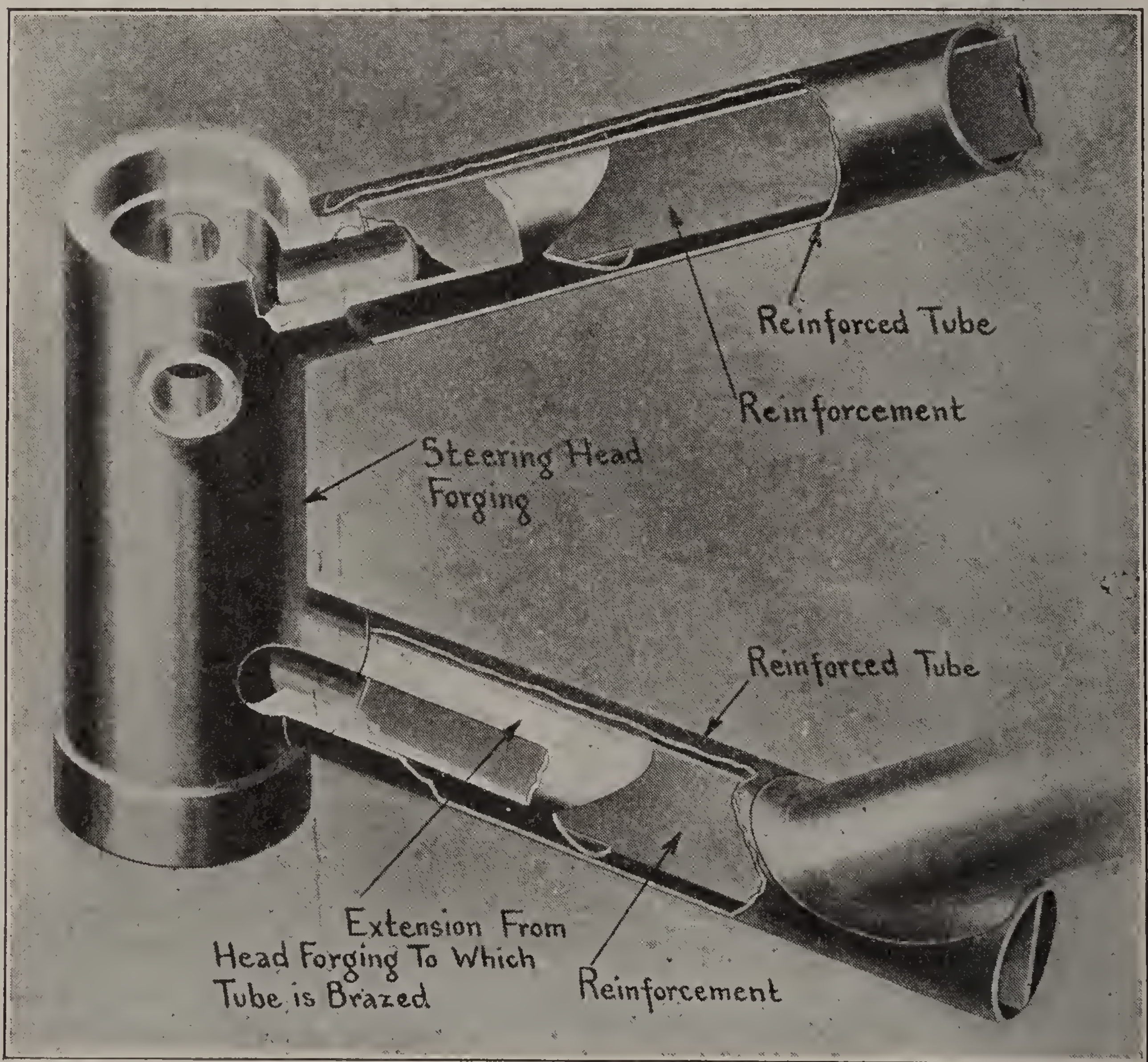


Fig. 222.—Steering Head Construction of Indian Motorcycle, Showing Internal Reinforcement and Method of Obtaining Strength While Using the Flush Joint Construction.

reinforcement is shown at Fig. 222. Another reinforcement which is even stronger than the single vertical member that bisects the tube into two D-shape or semi-circular sections is in the form of a triangular tube securely attached to the interior of the round frame tube. This tubing is used on the Emblem motorcycle, and is shown at Fig. 223.

The sizes of tubing used depends upon the character of the reinforcement and the strength it is desired to obtain in the motorcycle frame structure, which, of course, depends largely on the size of the power plant installed. A frame that may appear light when viewed from the outside on account of using tubing of small diameter may actually be stronger and weigh more than a more substantial looking frame of large diameter tubing, because it would have thicker walls and perhaps a more substantial internal brace member. The accepted method of fastening the frame components together is by a combination of pinning and brazing. When the frame is first assembled, it is placed in an alining fixture which insures that all the tubes will fit the various fittings to which they are attached properly, and that the center line of all the tubes comprising the main portions of the frame coincide. The next operation is to fasten the members together by drilling holes through the tube, and fitting and driving steel pins through these to hold the members together so the frame may be handled during the brazing operation. This process consists of heating the portion of the frame where the joint is to be made to a considerably higher point than the melting point of the spelter employed in joining the parts. The frame tube and fittings are raised to just below a white heat, and the binding material, which is a brass alloy in a molten condition is poured in the minute open space between

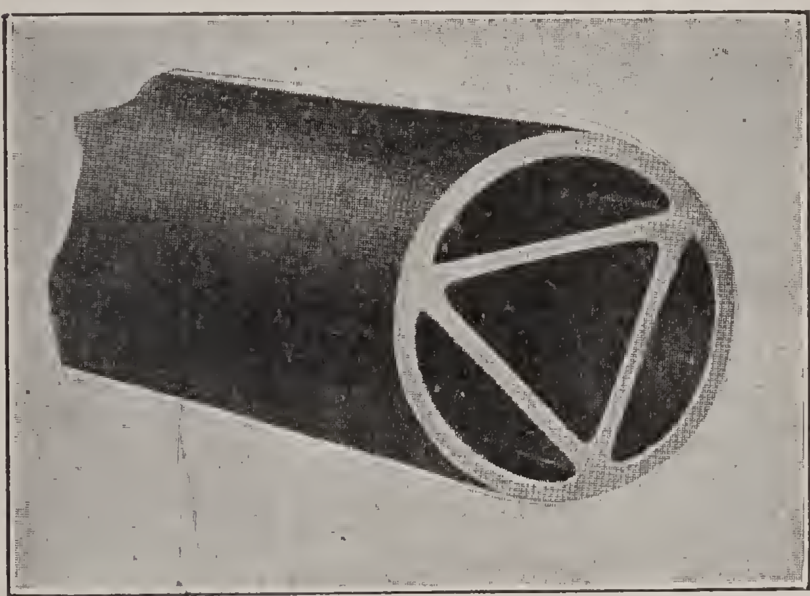


Fig. 223.—Tubing Used in Emblem Motorcycle Frame Has Triangular Reinforcement.

the frame tube and fitting at the joint. A flux, consisting of borax, is mixed with the spelter so it will flow readily between the tube and projecting member to which it is attached. When the joint is allowed to cool, the two members are held together by a thin layer of brass which forms a very strong joint that will give absolutely no trouble if it has been properly made.

There is also a tendency in modern motorcycle factories to use the oxy-acetylene flame in welding parts together, and this also makes a very strong joint. The process of electric butt welding or spot welding may also be used to advantage at various portions of the frame structure. Brazing is the method generally followed, because the process is well known and has been highly developed through many years of use in building bicycle frames. After the frame structure has been permanently assembled and all its components are held firmly together, the alining fixture is again brought into play and the frame straightened by suitable clamps if it has been knocked out of proper alinement by distortion due to the heat it was subjected to during the brazing process. After this, the frames are thoroughly cleaned, and all of the protruding spelter or flux at the joints is chipped or filed off. The frame tubes are then polished and smoothed by rapidly moving emery-coated cloth belts preparatory to the application of the enamel.

The size of the tubing employed averages about $1\frac{1}{8}$ inches diameter for the seat-post mast and the diagonal tube extending from the steering head. The upper and lower frame members that join the steering head to the seat-post mast and between the seat-post mast are usually of 1-inch diameter tubing. The rear forks and rear fork stays will be of $\frac{3}{4}$-inch or $\frac{7}{8}$-inch round tubing, though sometimes oval section tube may be employed for the rear forks. The front forks of most motorcycles are composed of oval section tubes which taper down from where it is brazed to the fork crown forging to the lower portion designed to carry the wheel hub, or the links to which that member is secured. Sometimes round tubing is used for front fork construction as shown at Fig. 218, though the general practice is to use the tapered section, flat oval tube. It is not considered good practice to use tubing much thinner than $\frac{3}{32}$-inch wall, and for the most part, even when it is well reinforced, tubing with a $\frac{1}{8}$-inch

thick wall is used for the principal frame members, such as the seat-post mast, the upper frame tube and the motor supporting loop member.

Foot Boards.—There is a growing tendency on the part of motorcycle designers, which has been fostered largely by the demands of the riders, to provide auxiliary foot-rests in addition to the usual pedals that have been used on motorcycles from the first. Foot-rests were first used on foreign machines, many of which have entirely discarded the pedaling cranks so widely used in this country. As these members are replaced by a simple starting crank or kick starter on motorcycles employing variable speed gears, it is necessary to provide some means for supporting the rider's feet. Naturally the simplest way was to braze extentions to the frame tube or attach foot-pads to the power plant in some way.

Some of the examples of foot supports used on American machines are shown in detail at Fig. 224. That at the top is the rigging used on the Excelsior motorcycle. The foot-rests are steel drop forgings of approximately the size of the average foot that are carried by a substantial auxiliary bracket member secured at its lower ends to one of the crank-case bolts and at its upper end to the diagonal frame tube by a substantial clip composed of two steel stampings held together by through bolts. The foot-rests are attached to suitable extensions by a hinge that permits of folding them up out of the way or to provide a safeguard against breaking them off or bending them, should the machine fall over. With the Excelsior assembly, a brake-operating pedal is included in order that the rider may work the brake as effectively when his feet are on the foot-rest as when they are on the pedal crank. The simple form shown in the lower left hand corner is used on the Schickel motorcycle, and consists of two simple cast aluminum members attached to a laminated leaf spring that is intended to provide a resilient support for the feet of the rider. The Iver-Johnson foot-rest also depicted at Fig. 224 is a folding type that offers a secure support for the rider's feet. It is carried by two hinges from a stamped steel member anchored to the frame.

In some machines, notably the Henderson and the two-speed Indian, the foot-boards are depended on entirely to support the feet of the rider, and no pedals are provided. There seems to be a ten-

dency toward the elimination of the pedaling gear that has for so long been a feature of bicycles and motorcycles, and while it was formerly an essential part of the machine on the early types without two-speed gears or free engine clutches and equipped with power plants of low rating, it is no longer necessary to assist the motor up

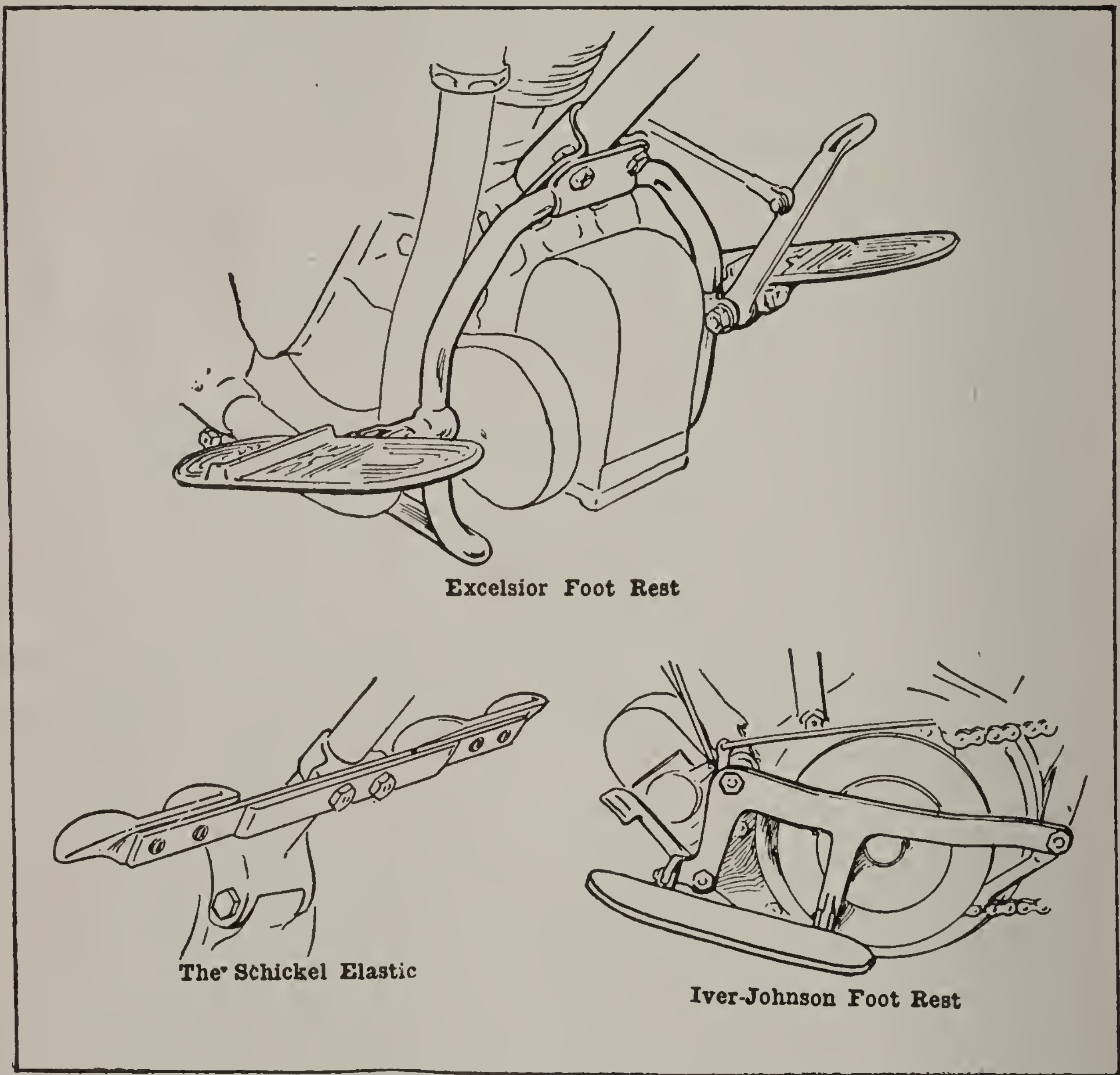


Fig. 224.—Examples of Foot Rest Construction Found on American Motorcycles.

a hill by vigorous pedaling or to constantly restart the motor after stopping it in traffic. The free engine clutch makes it possible for the rider to control his machine, and to bring it to a stop without affecting the motor, and the variable speed gear makes it possible to overcome all adverse conditions by the power of the motor alone. For this reason there is some talk about the elimination of the pedaling gear,

and the substitution of foot-rests and suitable controlling levers that will permit of positive motorcycle control. There is considerable to be said in favor of the pedaling gear, however, and its value is clearly established in the mind of the rider who has tried to start a stiff motor on a cold day by a more or less positive kick starter which does not permit of spinning the motor, as is possible when the effort of the rider can be applied with both feet through a substantial chain and crank to the rear wheel of the machine, which in turn rotates the motor crankshaft very briskly through the driving gearing, and which induces an obstinate motor to start even when it is difficult to vaporize the gasoline. Another feature is that brisk pedaling produces a hot spark at the spark plug, because the current production from the magneto is of more value when that member is rotated briskly. While it is thoroughly practical to start a four-cylinder motor by a starting crank, it is conceded that it is more difficult to start a single cylinder to twin motor with a starting handle, unless conditions are favorable. The writer believes that the pedaling gear is a desirable fitting, because it provides a means of supporting the rider's limbs when they become cramped from maintaining a constant position on the foot-rest. Pedals also permit of considerably more comfortable riding on rough roads than foot-rests do, because it is possible for the rider to relieve the saddle of his weight when running on rough ground by using the pedals for support. They are also valuable in providing a positive control of the braking and coasting hub which forms an essential part of many American motorcycles of modern design.

Rear Wheel Stands.—The motorcyclist of to-day is fortunate in having many devices included as standard equipment on the motorcycle he purchases, that had to be bought as an accessory or that could not be obtained at any price with the early machines. No motorcycle sold at the present time would be considered complete without an integral stand by which the rear wheel can be raised from the ground and the machine kept upright when left by the rider. It is not more than six years ago that the portable stand which is now considered indispensable was unknown. If it was necessary to stand the machine up, it had to be leaned against some wall or tree which did not always prove to be as secure a backing as the rider wished, because the machine might slip from its upright position, and when

the rider returned to his mount he was just as apt to find it lying on its side as in the upright position that he left it in. If it was necessary to raise the rear wheel from the ground, as in changing a tire or in making adjustments to the brake or hub, considerable ingenuity was necessary to improvise a suitable support for the rear end from a couple of boxes, odds and ends of boards, or even piles of bricks.

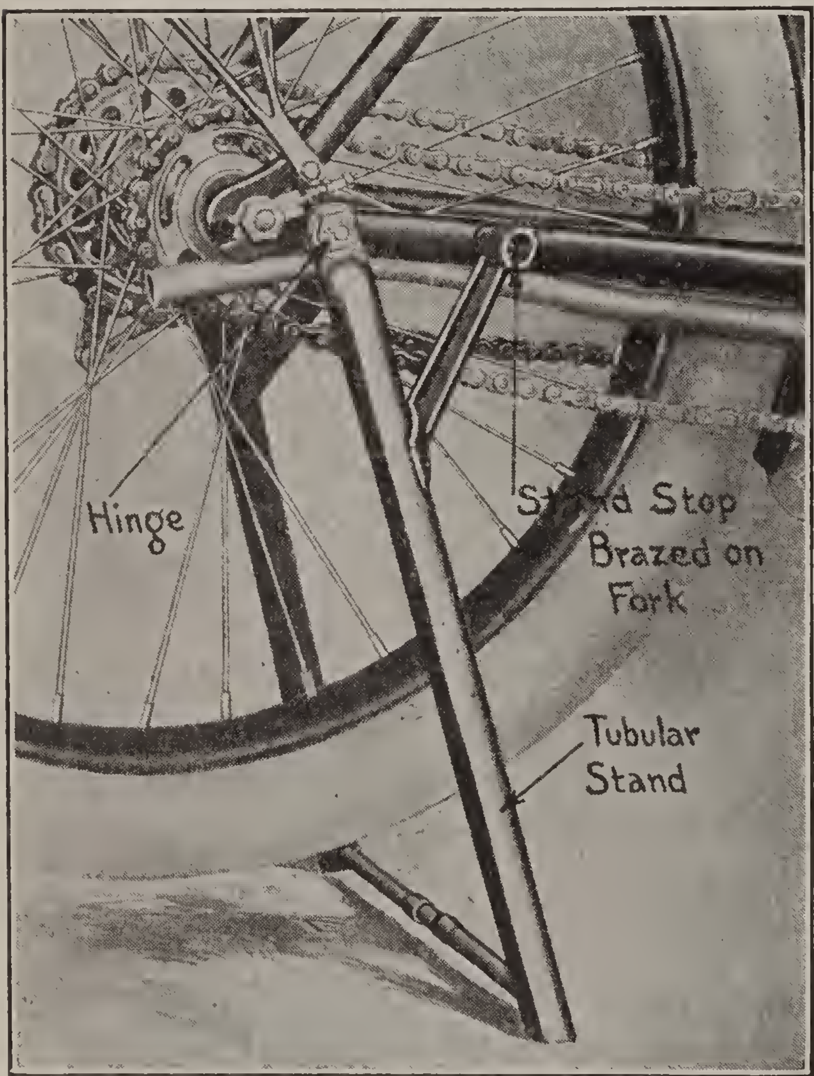


Fig. 225.—The Indian Rear Wheel Stand.

It is said that the first stand was offered by the Hendee Manufacturing Company for use in connection with the Indian motorcycles, during the early part of 1908. This consisted of two separate supporting members or legs fitted with clamps designed for attachment to the rear fork stays and hinged so the leg section could be folded up and away from the ground when the device was not in use. While this was a big improvement, it had the grave defect that it could not be used very well on soft ground, as the limited amount of contact at the lower portion of the legs would permit one or the other to settle into the earth, and either allow the machine to fall over or would permit the rear wheel tire to drag against the ground when the motorcycle was being tuned up on the stand.

At the present time, the stands are made with a cross piece at the bottom, which not only serves as a reinforcement but which provides an added means of support on soft ground. A motorcycle stand must

be light, strong and rigid. It must be applied so it can be swung into place easily and securely fastened out of the way when not in use. The stand at Fig. 225 is a tubular construction employed on the Indian motorcycle. It is hinged at its upper end to the slotted plate member or rear hub carrier at the point of intersection between the rear forks and rear fork stays. Two arms or projecting members of T section are brazed to the stand tubes, and are of such form that

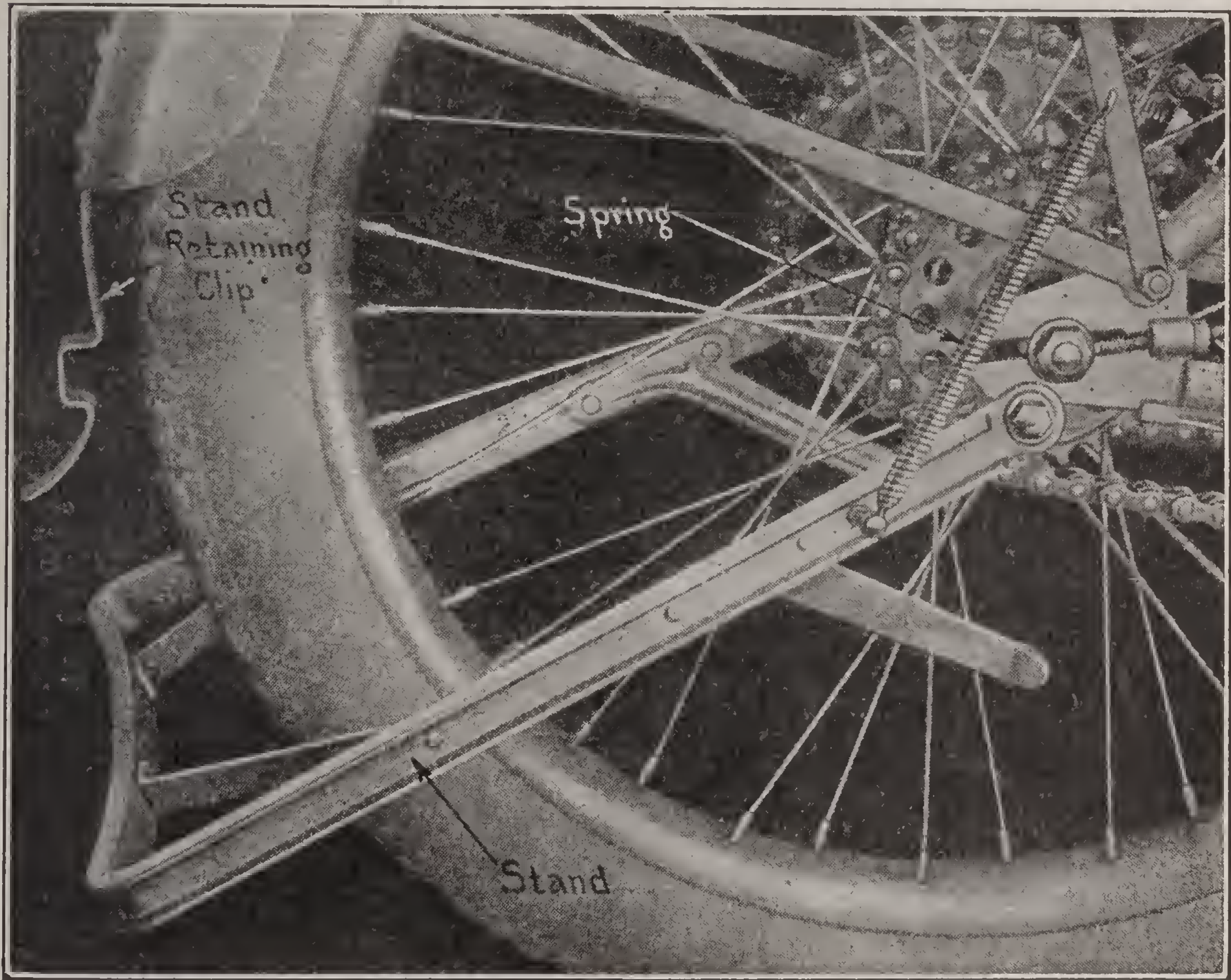


Fig. 226.—The Automatic Stand Used on Eagle Motorcycles.

they will rest against suitable stops on the frame. The stand at Fig. 226 is that used on the Eagle, and is an automatic type. Instead of tubing, channel section steel with substantial bracing members and forged arms is employed. The arms have a fork end at their upper portion that rests against the frame tube when the stand is in its operative position. A pair of tension springs are provided to return the stand to the position it occupies when not in use, automatically as the motorcycle is pushed off of the stand. The springs

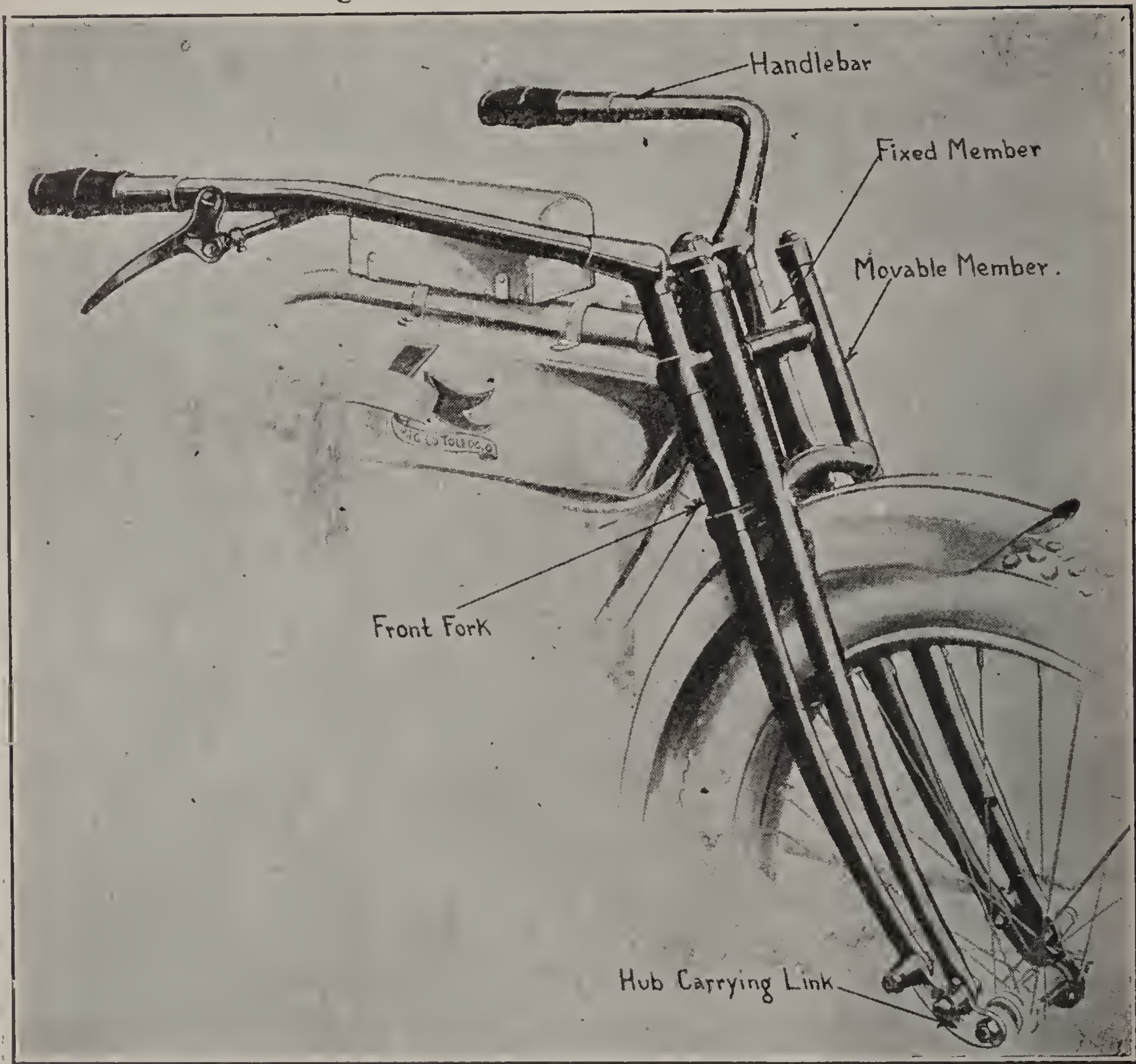


Fig. 227.—The Yale Spring Fork Construction.

draw the member into the stand retaining clip in the form of a piece of spring steel securely riveted to the lower portion of the rear mud guard. The front wheel stand which forms an item of equipment on many European machines and which has been previously illustrated is not supplied as a standard fitting on any of the American types, though some have been fitted to their machines by experienced riders familiar with the advantages obtained through its use.

Spring Forks.—One of the first concessions made for the comfort of the rider was the application of a resilient support for the front end of the frame in order that the shock incidental to operation over rough roads would be taken by springs instead of transmitted directly to the handle bars of the machine. This jarring promoted fatigue be-

cause of the shocks the rider's arms received. Even the earlier forms of saddles were comfortable, inasmuch as they were provided with fairly resilient springs or were well padded, so the attention of the designer was directed first to spring fork development on account of the complaints of the riders of the vibration at the handle bars. Spring forks have been made in infinite variety, though the object of all designers is to obtain the resilient feature without sacrificing strength unduly.

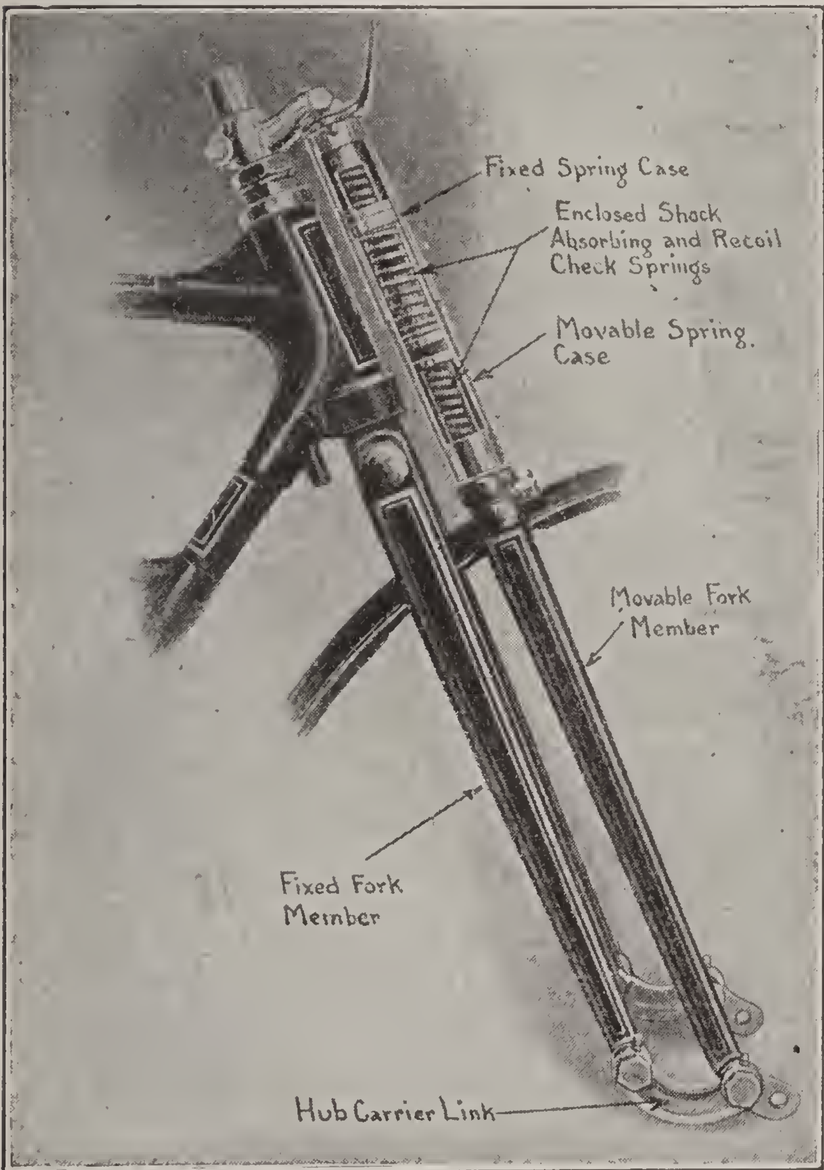


Fig. 228.—Sectional View of the Spring Case of Reading-Standard Spring Forks, Showing Load Carrying and Recoil Check Springs.

Two types of springs have been utilized to take the shock imposed on the front wheels. When coil springs are employed they are usually housed in casings of tubular form, though with leaf springs the resilient member is necessarily exposed. The fork used on the Yale motorcycle is shown at Fig. 227. It consists of two members, a fixed fork attached to the steering head in the usual way, and a movable fork. An extension piece carried from the fixed fork is mounted between springs at the upper end of the movable member, while the lower portion is attached at the center of the hub carrying link members. These are attached to the wheel hubs at one end and fulcrum on suitable bearing studs attached to the fixed fork end at the other. When the wheel encounters an obstacle, the hub carrying

link will move on the supporting bearing, and will force the movable member upward. This motion is resisted by the extension forming part of the fixed fork and by a spring carried below the extension in the upper portion of the movable fork tube. Another spring is mounted above the extension in order to prevent rapid rebound. The sectional view of the spring fork used on the Reading-Standard shown at Fig. 228 shows another application of the spiral spring principle. The movable fork member is attached to the hub carrying links in the same manner as previously described, and carries two spring members inside of a movable spring case which is guided by a fixed spring case attached to the upper portion of the steering head. The shock absorbing and recoil check springs are clearly shown and both are thoroughly encased and protected inside of the spring casing.

The application of the laminated spring to secure resilient wheel support was first tried out on the Marsh-Metz motorcycles, and has been retained on the modern product manufactured by these interests which is known as the "Eagle" motorcycle. This construction is clearly shown at Fig. 229. The front hub is carried by links which fulcrum on suitable bearings at the end of the fixed fork assembly. Attached to the plate that takes the place of the usual fork crown is a six leaf spring, and from the eye at the forward end of this member a movable fork member composed of two steel rods passes to the front hub carrier. As the wheel is moved by irregularities on the road surface, it is apparent that the leaf spring will be raised and that the shock will be absorbed in this manner.

The cradle spring fork which is an important feature of design on the Indian motorcycles is shown at Fig. 230. The advantages claimed for this type of spring include maximum flexibility, which is said to be produced by the curved end of the lower leaves, and the quick dampening of the oscillations or absorbtion of rebound due to the friction between the spring leaves. The spring fork of the Indian motorcycle is of the trailing type, which means that the hub axle follows the forks instead of having the hub mounted ahead of the fork as is also common practice. The advantage of the trailing hub is not as clearly realized as it should be. With the forms in which the hub is carried ahead of the fork, when the wheel is raised, it is apt to produce an upward movement of the entire front end of the

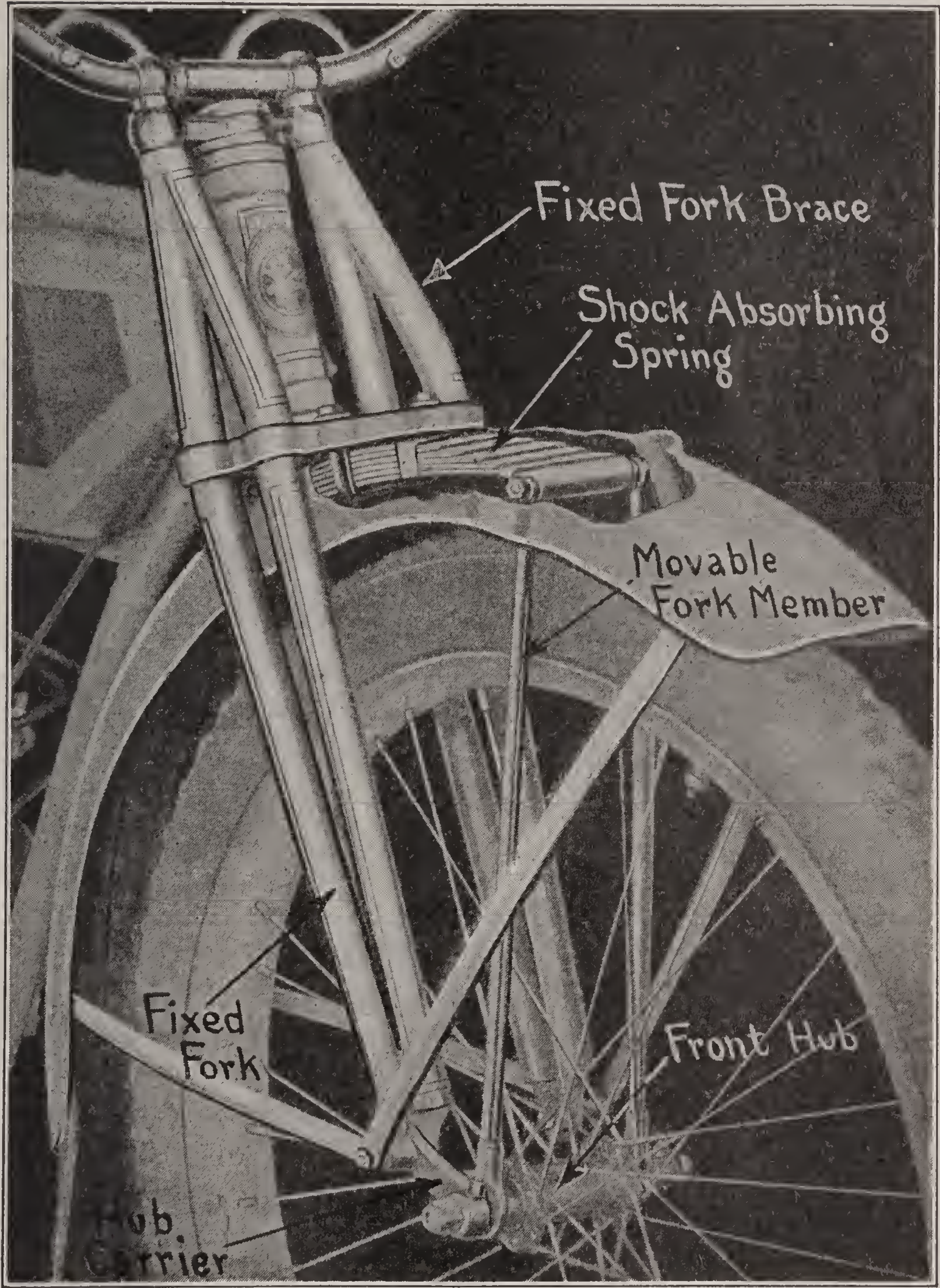


Fig. 229.—Leaf Spring Used on the Eagle Motorcycle to Control Movable Fork Member.

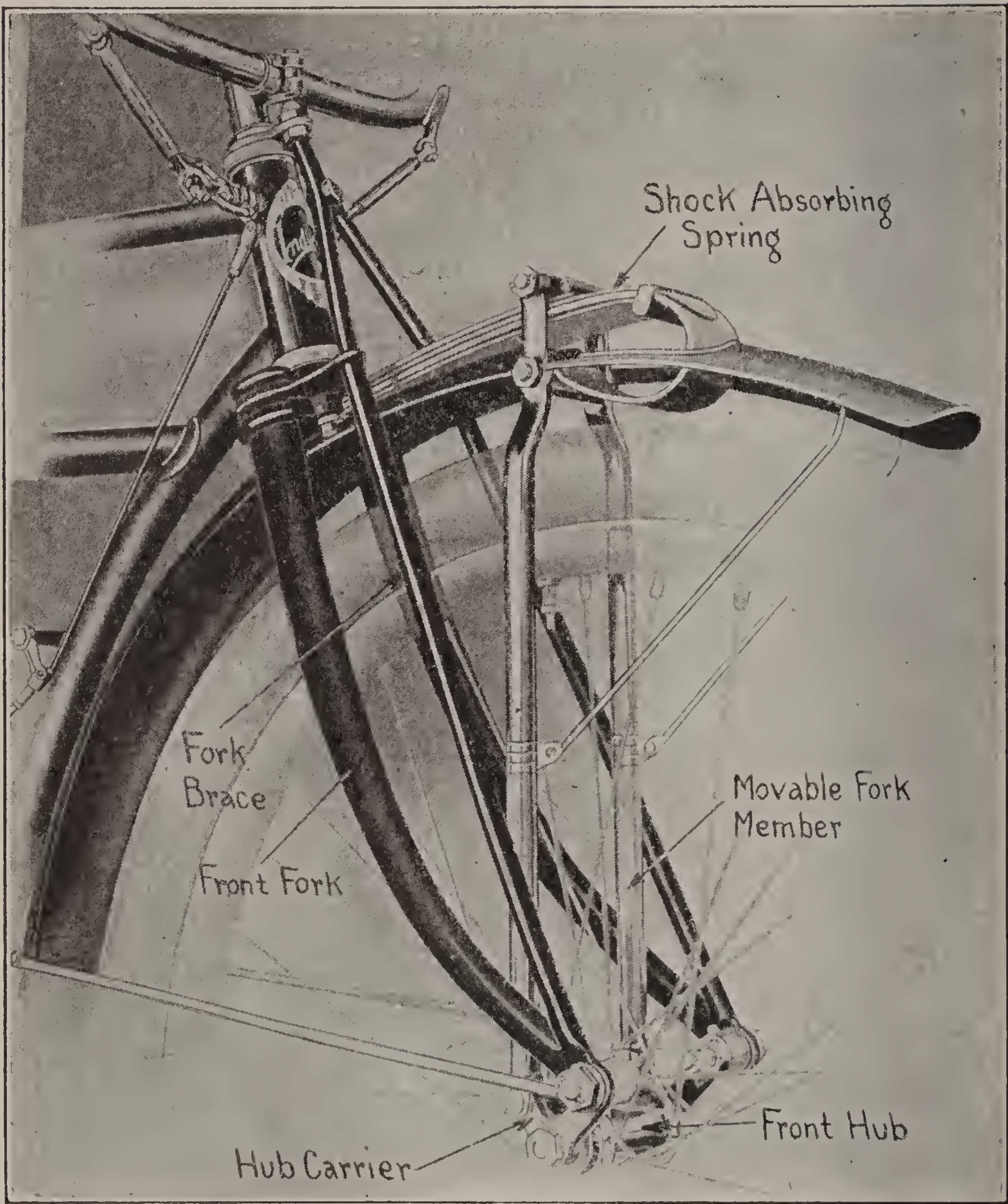


Fig. 230.—The Indian Cradle Spring Fork.

machine because a certain portion of the shock is transmitted by the hub carrier link directly to the fixed fork members as the wheel surmounts the obstacle. With the trailing hub construction, which is clearly outlined at Fig. 230, any movement of the wheel will affect only the shock absorbing spring.

The advantage of the trailing hub construction may be readily

grasped by comparing its action to that of a wheelbarrow when it passes over a raised object. If a wheelbarrow is pushed against a curb, for instance, it will be found difficult to force it over the obstruction, whereas if it is pulled over it will surmount a high curb with comparatively little effort on the part of the person wheeling it. The usual method of supporting the front wheel ahead of the fork may be likened to pushing a wheelbarrow over; the trailing hub action is the same as when it is pulled over the obstruction.

The fixed fork member of the Indian machine is well braced by a tubular arch member extending from the top of the steering column to the lower portion of the fixed fork. The hub carrier links are attached at their front end to the fixed forks, carry the wheel hub at their center, and the movable forks at the back end. The curved lower leaf of the shock absorbing spring provides a certain degree of flexibility which makes the wheel respond to slight irregularities of the road surface, and when greater resistance is encountered the entire spring is brought in action because the movable fork member exerts its pressure against the lower leaf at a point calculated to bring the remainder of the spring leaves in action.

The foreign spring forks vary from the American designs, and the preference seems to be for coil springs as shock absorbing members, which are invariably exposed. A number of typical English spring forks are shown at Fig. 231. In the member outlined at A, the wheel is carried in a substantial movable fork member, that is secured to the member passing through the steering head by means of distance links which permit a certain amount of up and down motion, but which do not allow the wheel to move backward appreciably. In most American designs, the wheel may move backward as well as up and down. At the lower portion of the piece passing through the steering head a pair of spiral springs are mounted which are attached at their lower ends to extensions brazed to the fork tube. When the wheel meets an obstruction, its upward motion is resisted by the springs which are under compression while the violent rebound is checked by the tension resistance of the spring. In the form shown at B, the fixed fork member is fulcrumed on a pair of links which are attached to the piece passing through the steering head. The shock absorbing spring is also secured to the steering head member and

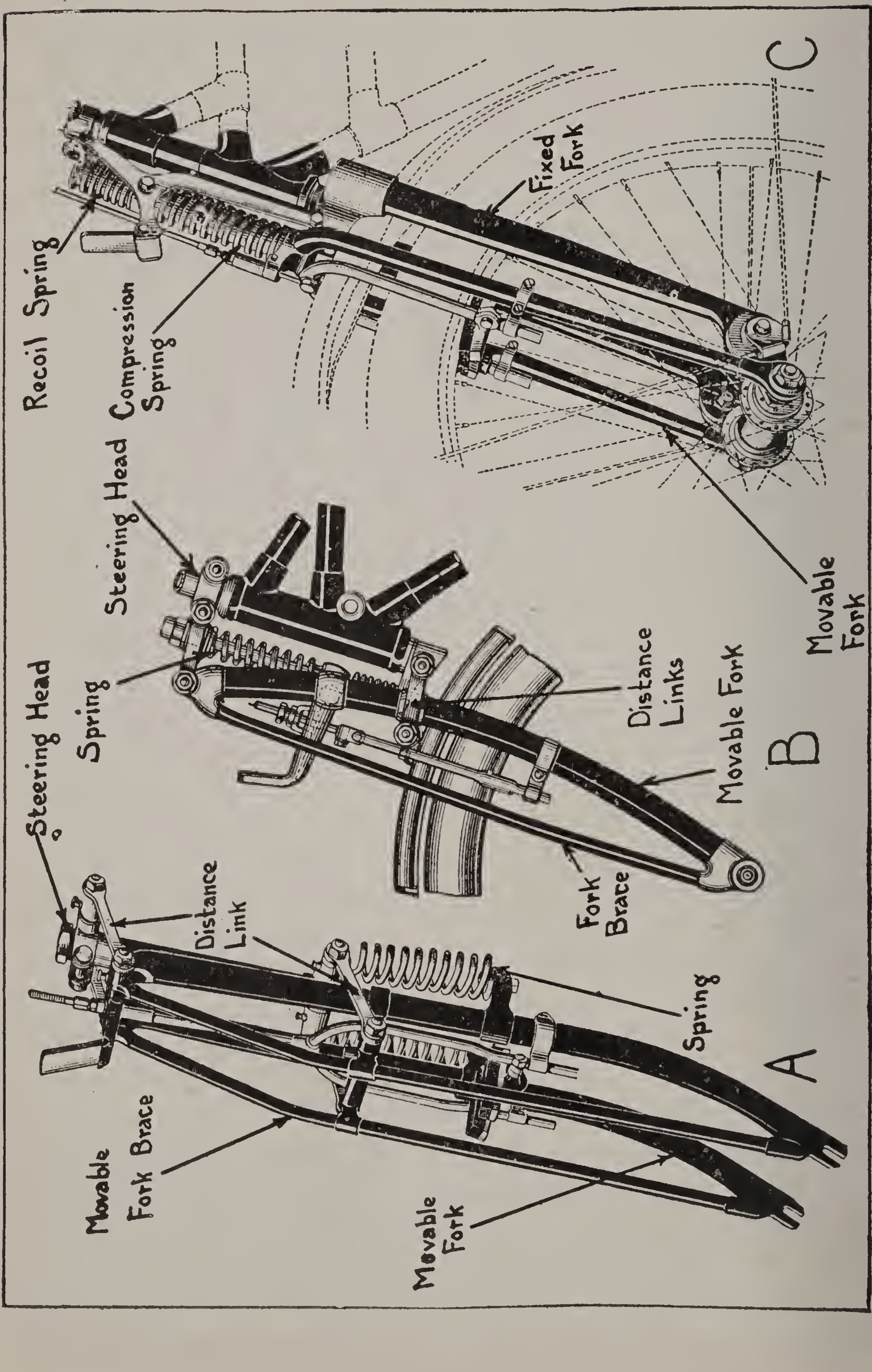


Fig. 231.—Spring Forks of English Design in Which Coil Springs are Employed Exclusively.

resists upward motion or vertical travel of the fork member, which can move in that plane as the distance links oscillate on their bearings. The upward motion is resisted by the upper coil spring while the recoil is checked by a suitable member at the lower part of the steering head. Both springs are under compression.

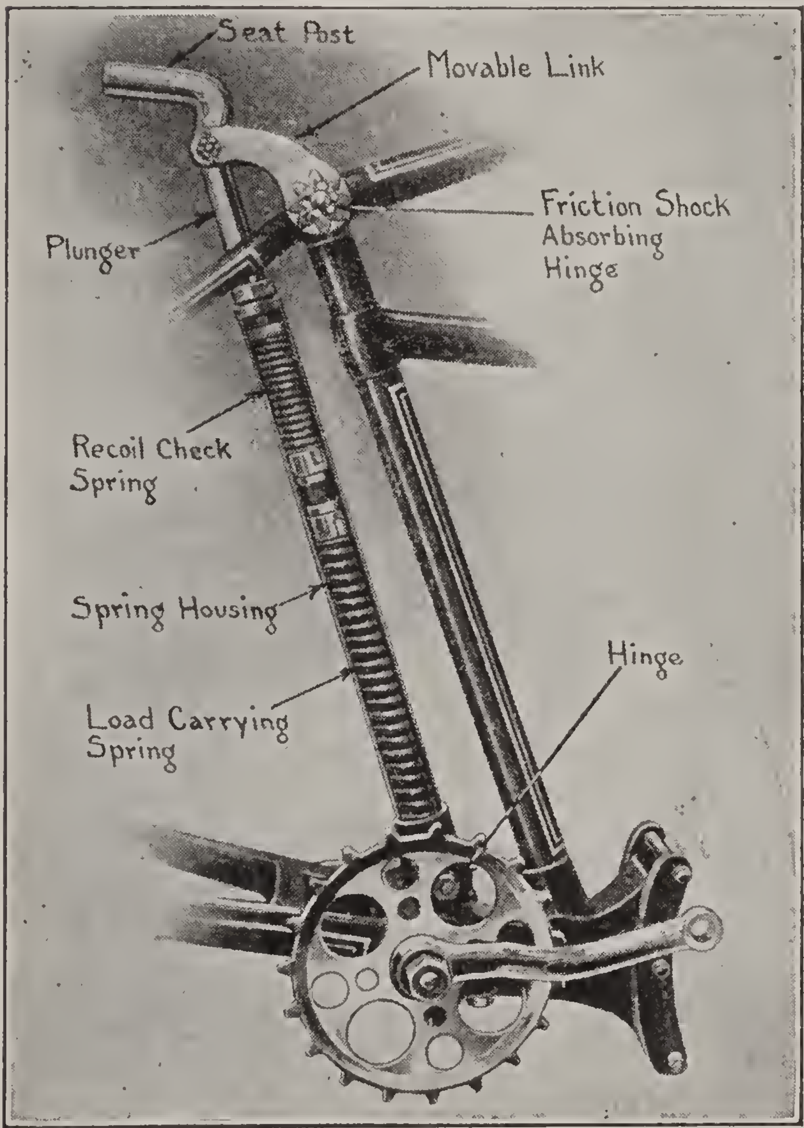


Fig. 232.—Spring Supported Seat Post of Reading-Standard Motorcycle.

Another form which is very similar to the American design depicted at Fig. 228, without enclosed springs, is shown at C. In this, the lower of the two springs is a compression member that is provided to absorb the shock, while the shorter of the two or upper spring is used to check the recoil. The hub in this construction is carried in a movable fork member which is kept in proper relation with the fixed fork by suitable distance links. A point that should be noted by the reader is the system of applying a pair of brakes that act against the front wheel rim on all three of the forks shown at Fig. 231. This brake is actuated through the medium of Bowden wire control running to a suitable handle on the steering bar. The U-shape member carrying the brake blocks or contact shoes is guided at its lower ends by clips secured to the fork side, while it is steadied at the upper end by a bearing through which the wire or a lifting rod passes

Spring Supported Seat Post.—After the springing of the front

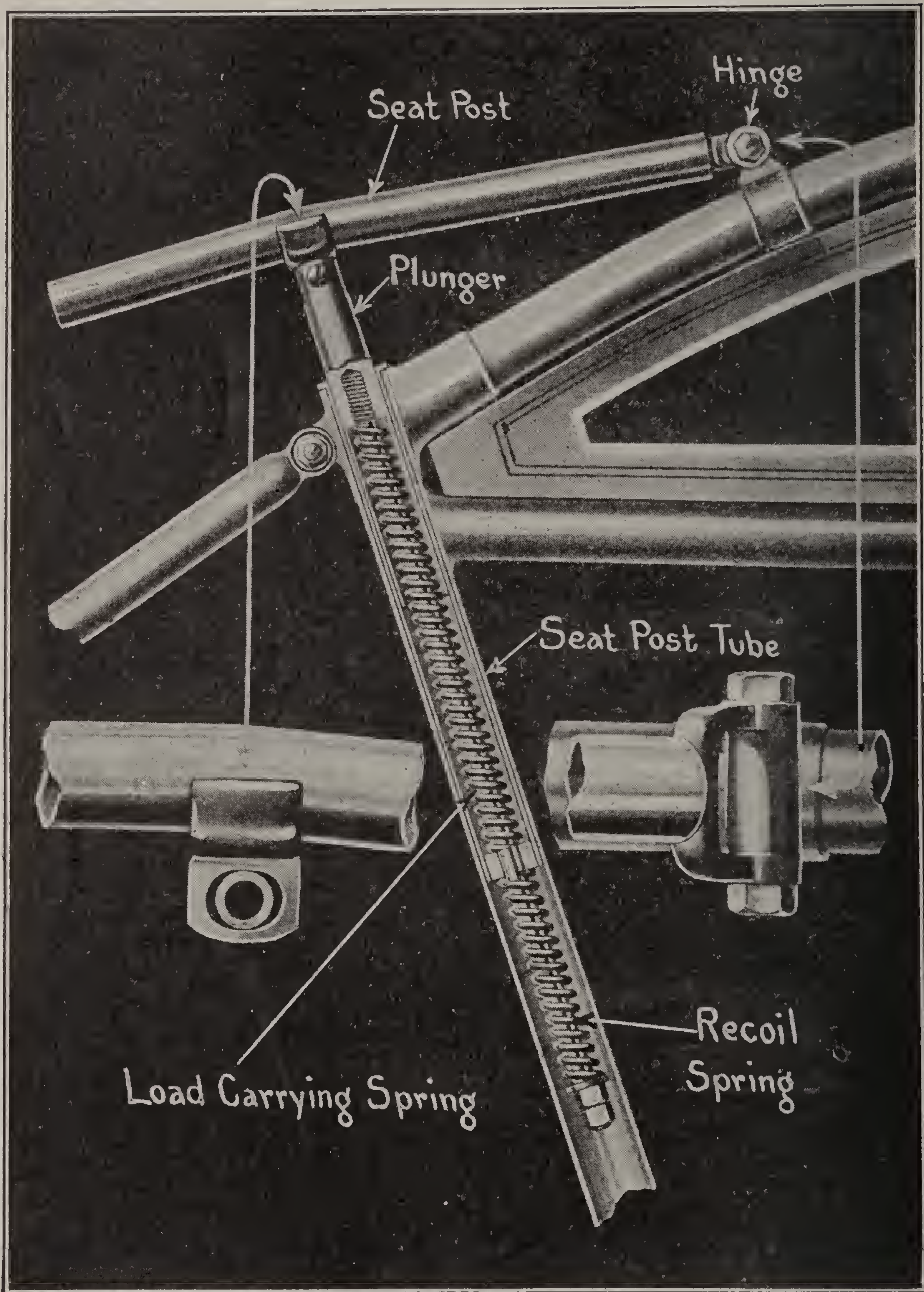


Fig. 233.—Spring Seat Post Used on Eagle Motorcycle.

end has been satisfactorily accomplished by the use of spring forks some of the designers began to consider the best method of eliminating the jar at the rear end of the machine. Some of the manufacturers have adopted a resilient frame construction with the idea that this would suspend the power plant on springs, as well as the rider. Other makers contend that the spring supported saddle coupled with a resilient spring fork is all that is needed to insure comfort of the rider, and reduction of shock on the machine.

The spring seat post attachment employed on the Reading-Standard motorcycle has demonstrated its efficiency and is very simple. As is true of the spring fork previously described, the resilient support of the saddle is attained by the use of coil springs protected by and housed in a tubular housing hinged at its lower portion just forward of the pedal crank hanger, and maintained in proper position at the upper end with a movable distance member or link. The seat post is extended to form a plunger that is guided by a suitable bearing at the upper end of the spring housing. The long coil spring is the load carrying member, while the shorter spring at the upper end is a recoil check. Another feature that tends to prevent too rapid movement of the seat post is the friction shock-absorbing hinge by which the movable link is held to the seat post tube.

The spring seat post used on the Eagle motorcycle, and illustrated at Fig. 233, is similar in construction to that just described, though it is different in detail and application. The seat post is hinged at its upper end to a clip attached to the upper frame tube. It is adapted to bear on a plunger member that projects through the seat post tube, which also serves to house the load-carrying and recoil spring. A simple application of a spring-supported seat post is shown at Fig. 234. The forward end of the seat post is hinged to the frame, while the rear end is secured to a conical spring that bears on a supporting member attached to the rear fork.

The method of mounting the saddle on the Yale motorcycle, shown at Fig. 235, is similar except that two springs are used, one at either side of the seat post tube in supporting the saddle. These are coil springs and are intended to supplement the action of the members with which the saddle itself is provided. Another application of a spring seat post is shown at Fig. 236, as applied to the Fielbach

motorcycle. The saddle supporting member is in the form of a bell crank, the long arm of which carries the saddle, while the short arm is attached to a plunger that works through the lower of the two upper frame tubes which serves as a housing to retain the load-carrying and recoil-absorbing members.

Spring Frames.—There is a marked distinction between spring seat posts and spring frames, and this is well shown by comparing

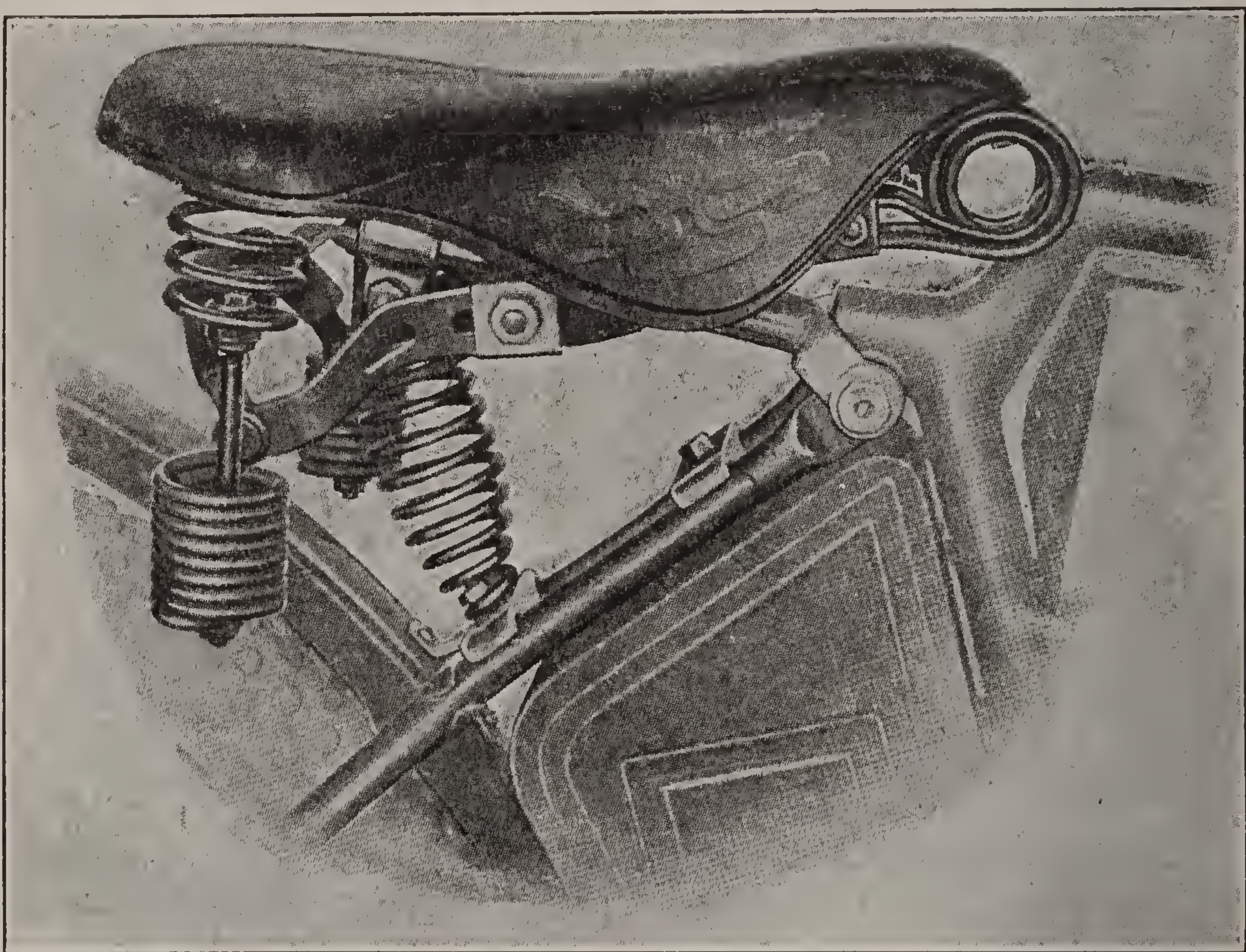


Fig. 234.—Application of Single Coil Spring to Support Seat Post of Thiem Motorcycle.

the two different methods shown at Fig. 237. That at A is a simple spring frame, which means that the weight of the rider is carried by a frame which in itself is capable of movement, and that the same frame to which the power plant is secured also directly supports the weight of the rider. The rear hub of the Pope motorcycle is mounted in simple forged yokes that are guided by plungers extending through bosses at the end of the U-shape brackets attached at the rear of the frame. The heavy coil springs are under tension and the tendency of

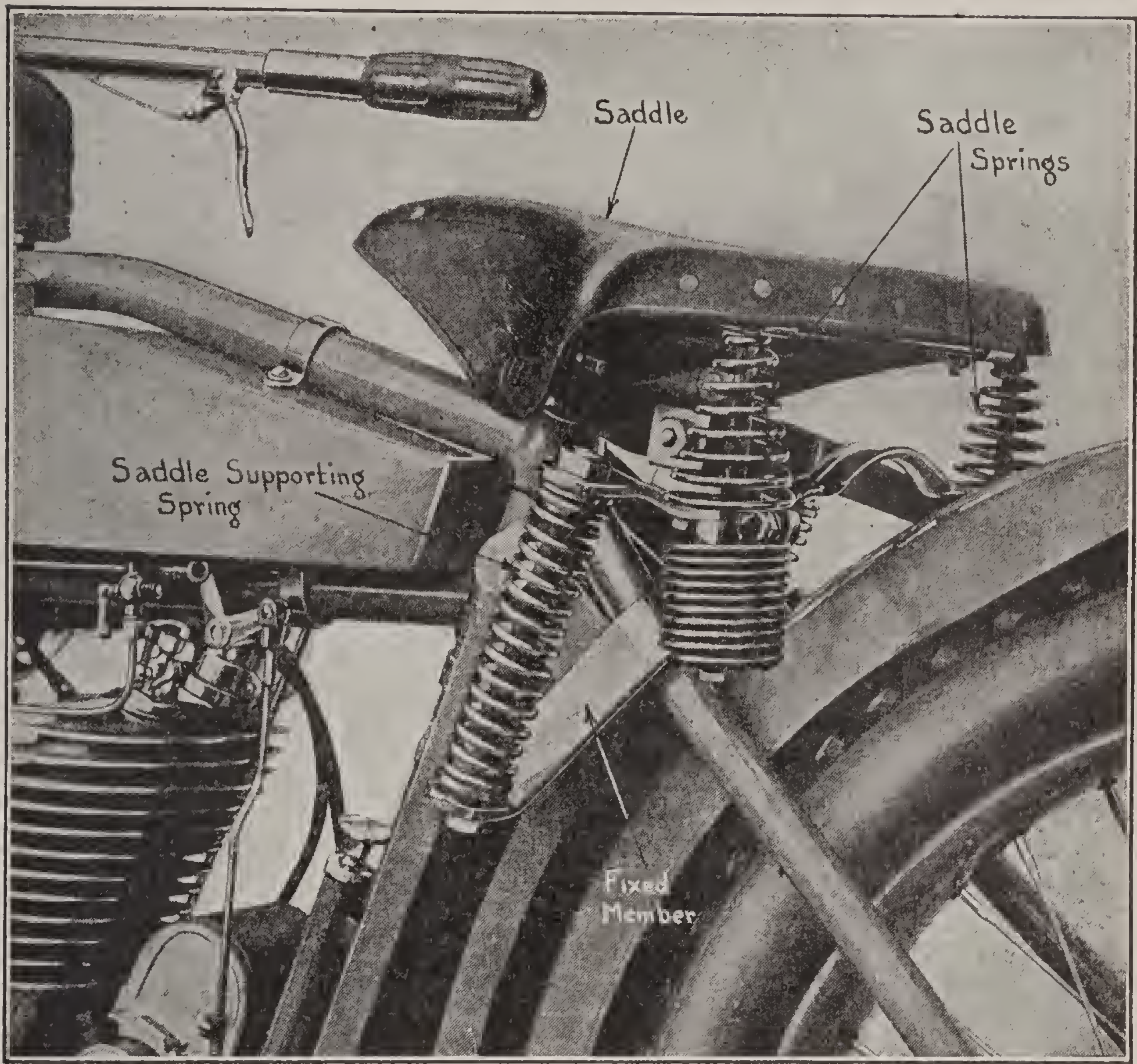


Fig. 235.—Double Coil Spring Supported Saddle Carrier of Yale Motorcycle.

the upward movement of the rear wheel when it strikes an obstruction is to extend rather than compress them. The spring-supported seat-post representative of the other construction, shown at Fig. 237, B, also includes a coil spring under tension. The seat post is guided by distance links, one end of the spring being attached to the frame, while the lower end is secured to the movable seat-post member.

The cradle spring frame utilized on the Indian motorcycle is conceded to be one of the biggest steps forward ever made in the development of the motorcycle frame. The construction is not unlike that of the spring fork except that two load-carrying springs are used, one at each side of the wheel. The wheel hub is carried in a movable rear fork stay hinged at its forward end to the lower portion of the tube

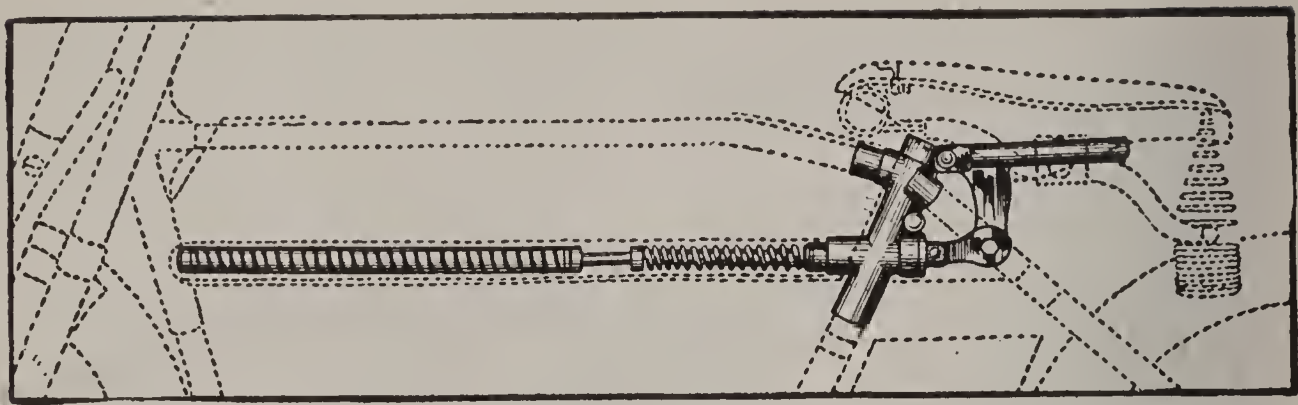


Fig. 236.—Method of Housing Spring Controlling Action of Fielbach Seat Post in Frame Tube.

that takes the place of the seat-post mast of conventional design frames. The load-carrying springs are attached to a semi-steel casting member in the form of a horseshoe that takes the place of the usual seat-post cluster. A movable rear fork member is attached to the springs in the same manner as the movable fork member of the spring fork assembly is, and is hinged at its lower portion to the hub-carrying plates. It will be evident that with this construction the rear wheel may move independently of the main portion of the frame that carries the weight of the rider and the power plant, and that the combination of this member with the effective spring fork should not

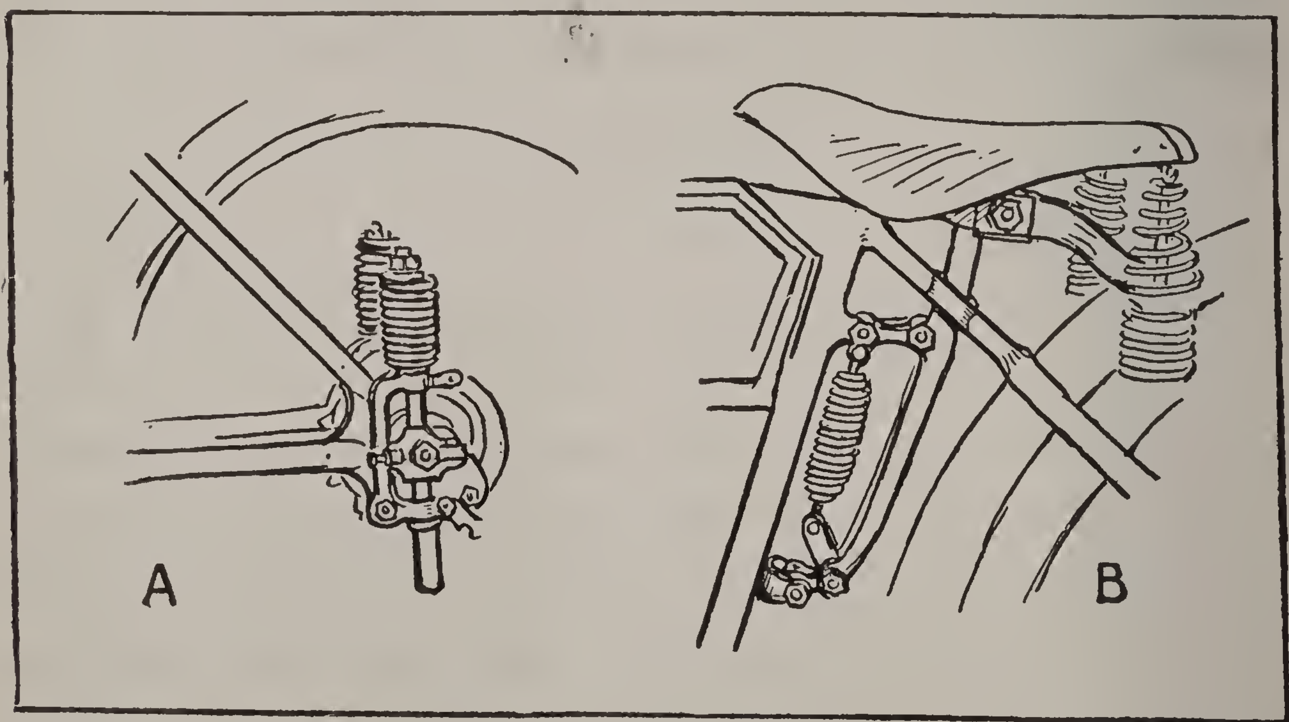


Fig. 237.—Examples of the Two Differing Methods of Providing Resilient Support for the Rider. A—The Pope Helical Tension Spring Frame. B—Tension Spring Supporting Movable Seat Post.

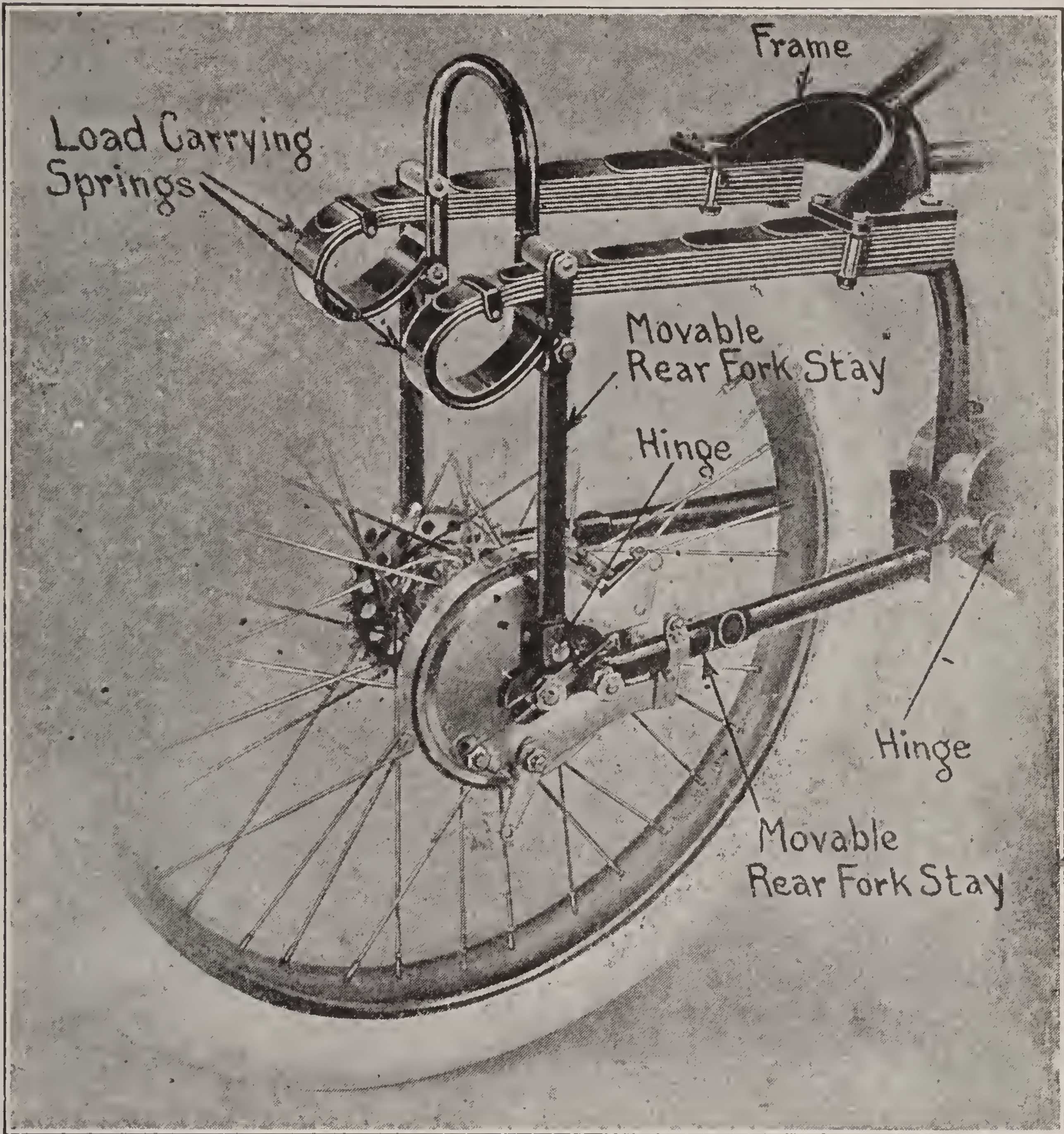


Fig. 238.—The Indian Cradle Spring Frame.

only provide for maximum comfort of the rider but contribute materially to the long life and endurance of the mechanism by insulating it from the destructive road shocks in a much superior manner to that which obtains in the conventional construction where the air-filled tire is the only resilient support.

Two spring frame constructions in which coil springs are used are shown at Fig. 239. That at A is the form used on the Merkel, and has been a feature of this machine for several years. The rear portion of the frame, which is comprised of the forks and rear-fork stays,

operates in the same manner as the spring forks in which the enclosed coil springs are used. The rear-fork stay members are employed to house the coil springs, while the front end of the fork assembly is hinged to the crank hanger in order to permit free movement of the rear portion of the frame. The method of incorporating a heavy compression spring in the frame of the N. S. U. motorcycle, a foreign design, is shown at Fig. 239, B. The application of four laminated leaf springs to support the rear wheel of an English four-cylinder

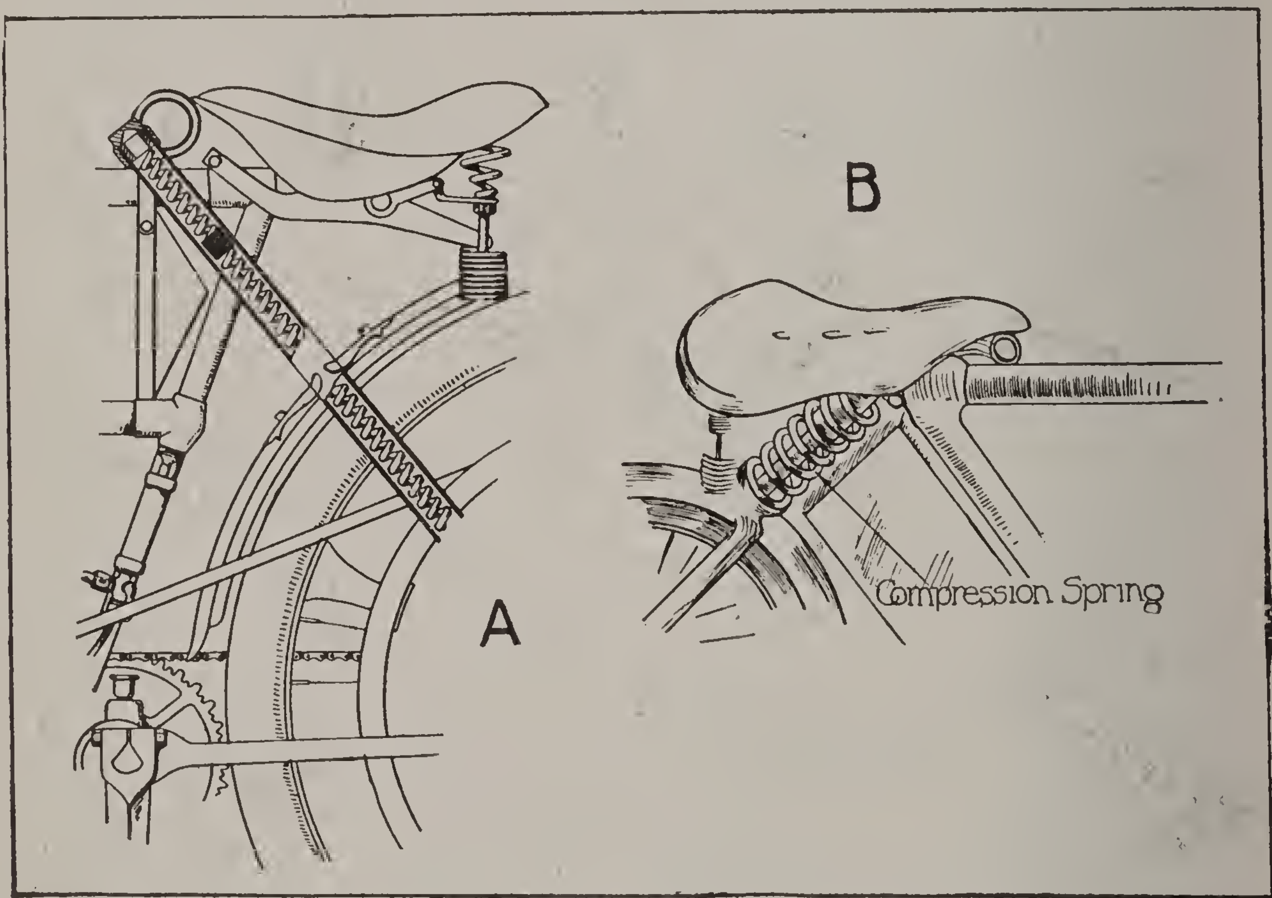


Fig. 239.—Two Methods of Incorporating Coil Springs in Spring Frames. A—Application in Merkel Rear Fork Stays. B—Compression Springs Used on N. S. U. Model.

motorcycle employing worm drive is shown at Fig. 240. In view of what has been presented before, and the complete explanations that have been given of spring fork and spring frame action, the method of operation of these various forms should be clearly grasped.

Saddles and Tandem Attachments.—The first motorcycle included practically all the parts of the bicycle without much change, and it was some time before some of the parts were altered or enlarged, even after considerable improvement had been made in motor

design and in the construction of the mechanism. One of the fittings that was not changed for several years because the designers had all they could do to make the mechanism reliable was the support or saddle for the rider. The saddles that had been used in bicycles were of simple form, usually consisting of a light wooden or steel frame covered with leather; in some cases a padding would be interposed

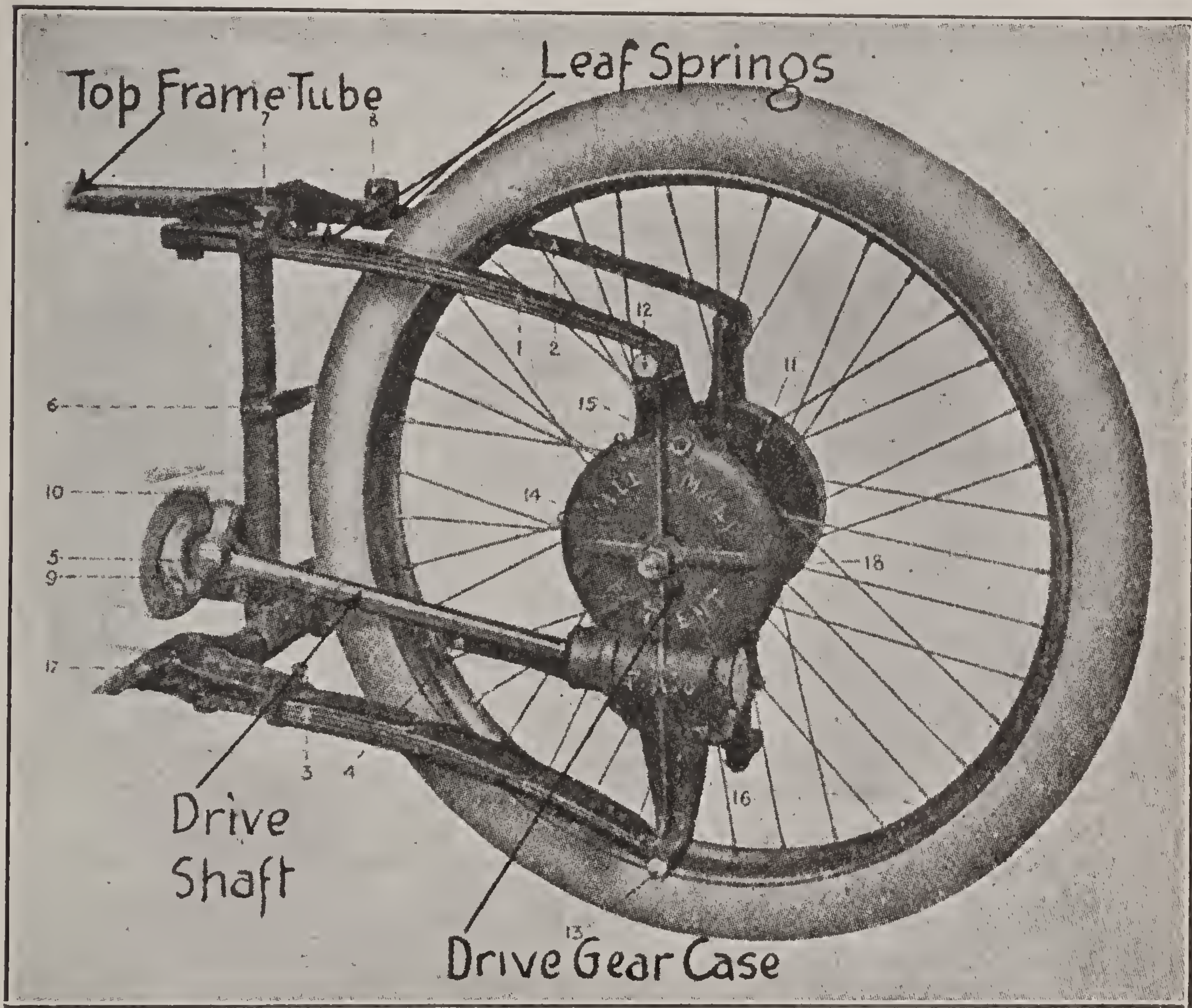


Fig. 240.—Method of Carrying Rear Wheel by Four Leaf Springs on T. A. C. Motorcycle.

between the leather covering and the base. Bicycle saddles were narrow, and they were very satisfactory on those machines where the riders weight was distributed to some extent on the crank hanger through the efforts made and pressure applied to the pedals to propel the vehicle. With the motorcycle, the rider did not have to pedal any more than was necessary to start the machine, which meant that practically all of his weight would rest on the saddle. Several

forms of bicycle saddles were made that provided a wide support, but it was found that these materially interfered with the effective action of the rider's limbs when pedaling. This objection did not obtain in the motorcycle and the saddles were gradually increased in size, both in length and in width, until the forms used to-day provide a secure and comfortable seat. It was not desirable to have a very resilient saddle on a bicycle because the spring detracted somewhat from the effectiveness of the pedaling. On a motorcycle, however, it was soon learned that it was much more uncomfortable to sit on an inflexible non-yielding seat on a machine going 35 or 40 miles an hour than was the

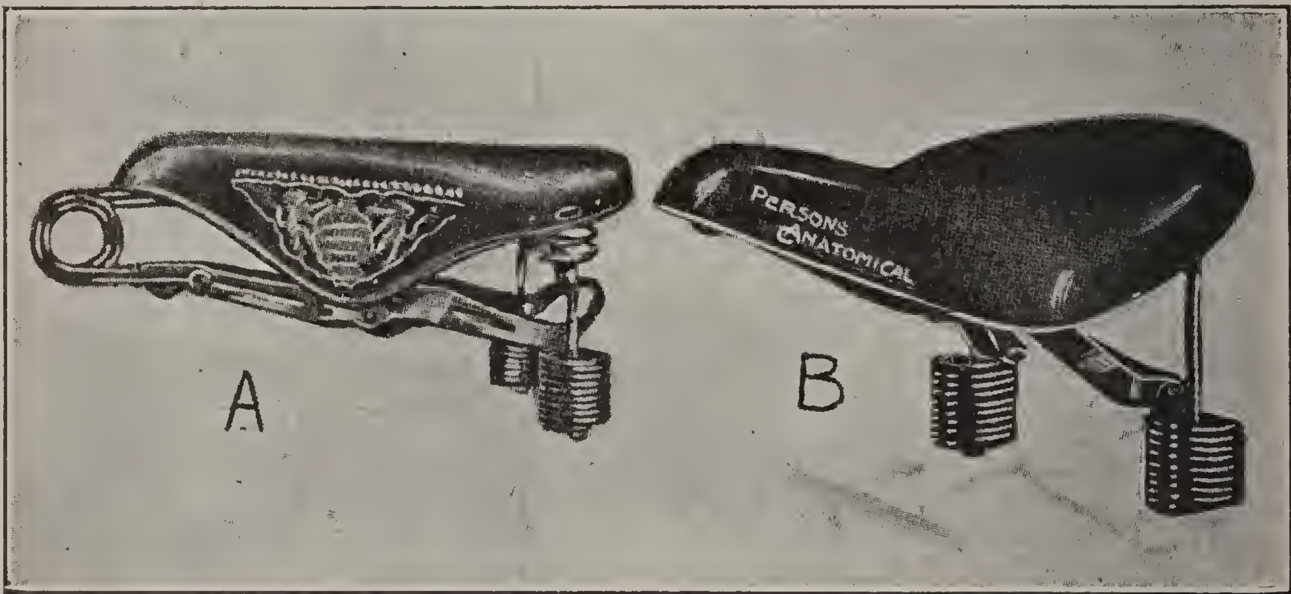


Fig. 241.—Typical Motorcycle Saddles.

case when traveling but one-third that speed on a bicycle. The saddle manufacturer was not slow in devising wide seats that were provided with substantial spring members in order to make them easy riding.

Two modern saddles are shown at Fig. 241. That at A consists essentially of a metal frame over which a leather seat is placed, the leather being kept under tension by the coil spring at the front end. This spring gives somewhat under the rider's weight, though the main reliance for easy riding is upon the coil springs at the rear of the saddle. The form shown at B is similar in construction as far as the frame work is concerned, except that the seat is formed to conform to the anatomy of the average rider and has a padded cushion interposed between the leather covering and the metal frame.

The arrangement of the springs used to support the rider in the

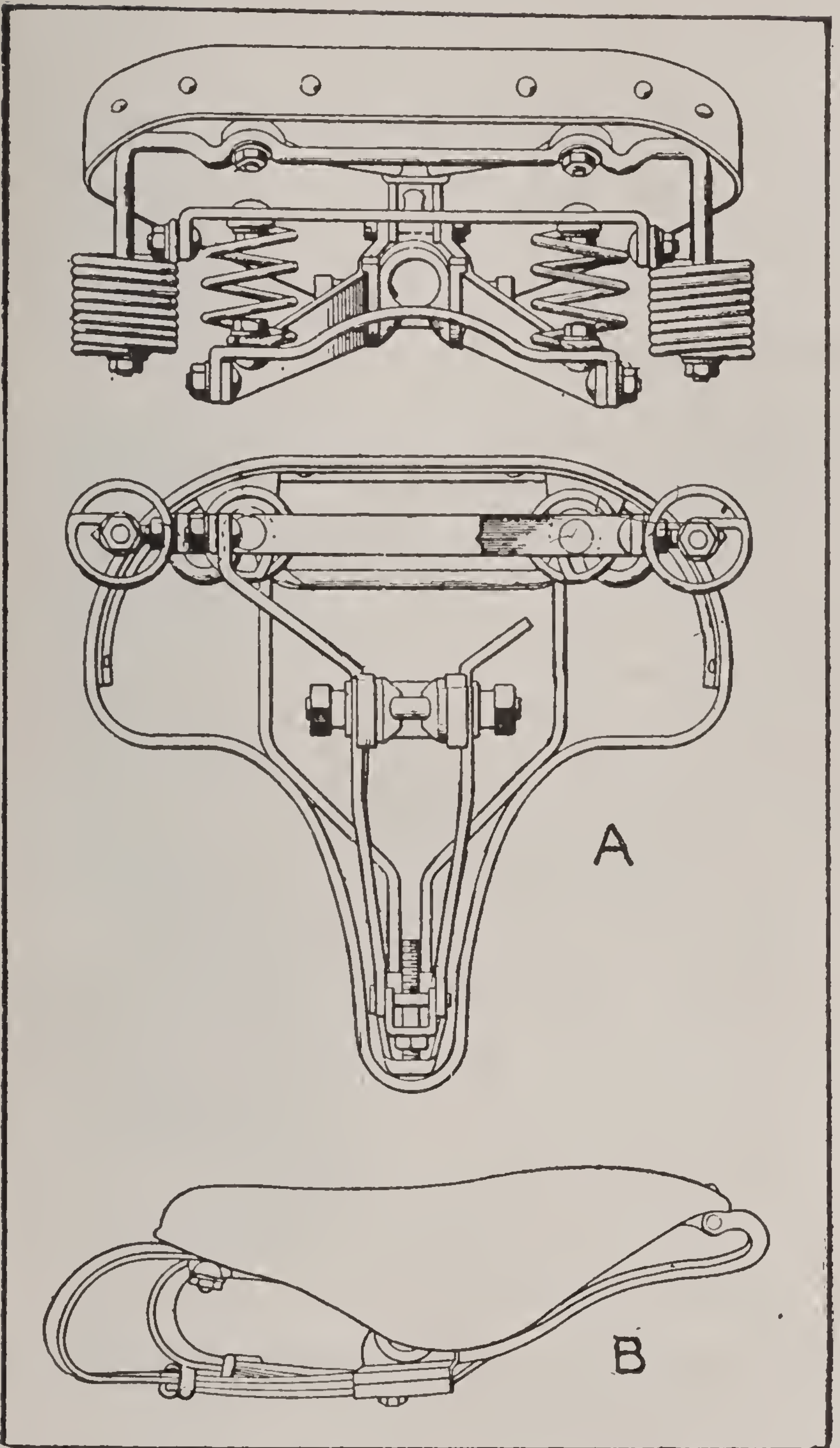


Fig. 242.—Showing the Two Forms of Springs Used in Supporting Motorcycle Saddles.

usual motorcycle saddle as well as the general construction of the form in which coil springs are used is clearly outlined at Fig. 242, A. The metal frame work with the leather coverings removed to show the arrangement of the parts of the Persons Champion Saddle is shown at Fig. 243. Coil springs are not the only type that have been adopted in saddle construction. A form in which leaf springs are used to support the rider's weight is shown at Fig. 242, B. Practically all saddles are provided with an adjustable clamp that permits of tilting the saddle to some extent and moving it back and forth on the seat post tube to adjust the seat member for different builds of riders.

While some of the early motorcycles were made in a tandem form, i. e., just the same as the two-passenger bicycles except for the addition of the power plant, this form of construction is now abandoned. The reason for discarding the tandem was that the machine was unwieldy and hard to handle if but one person was riding. For this reason, tandem attachments that would convert the ordinary form of one-passenger motorcycle so that two people can be carried effectively

have been evolved. A typical tandem attachment removed from the machine is shown at Fig. 244, while a similar device attached is depicted at Fig. 245. The tandem attachment in its simplest form consists merely of a supplementary rear fork member carrying a pair of foot rests or pedals at its lower end, and a saddle at the upper part. A brace extends from the top of the fork to the seat post cluster of the machine, and in most cases this brace carries a pair of non-movable handle bars by which the passenger may steady himself.

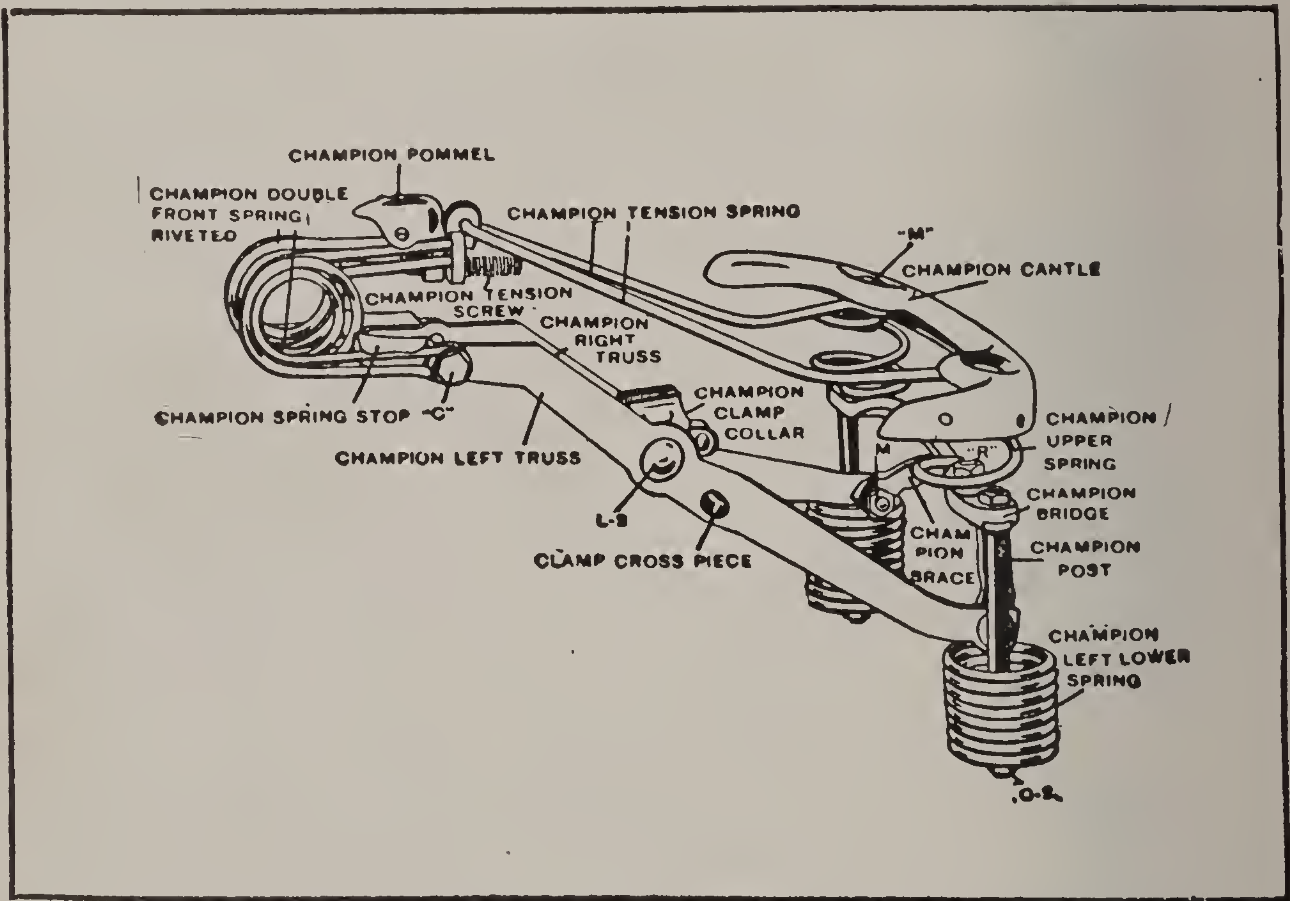


Fig. 243.—Steel Framework of Persons Champion Saddle.

Why Powerful Brakes are Necessary.—It is now generally conceded by manufacturer and rider alike that the motorcycle of to-day is practically a two-wheeled automobile capable of speeds rarely attained by the larger conveyance. Engines used are rated at from 7 to 9 horse-power, and these will usually develop twice their nominal rating. Larger motors call for heavier frames to carry them and the rider safely, more powerful transmission systems are fitted and spring frame and forks are also required to insure comfortable riding at high speeds over ordinary roads. All control elements must also be de-

signed with a view of giving the rider positive mastery of the machine. When one considers the momentum it is possible to attain with a vehicle weighing, with average rider, nearly 400 pounds, and capable of a speed of 75 miles per hour in many cases, the need of a positive retarding member or brake can be properly realized. Brakes designed primarily for bicycle service and increased in size without due regard to the stresses obtaining in motorcycles, cannot work adequately or prove enduring. The brake as well as the other parts of the machine must be increased in size and capacity to correspond in efficiency to the larger power plants now fitted. The problem is therefore essentially one of automobile design, and can only be solved by a correct application of motor car engineering principles.

Fig. 244.—Typical Tandem Attachment.

Why Coasting, Driving and Braking Hub is Used.—One of the most important accessories developed for the bicycle trade, and one which has contributed materially to the expansion of that business by promoting the comfort and safety of the rider was the coasting and braking hub. In this device, the motorcycle manufacturer obtained a rear hub construction, already highly developed, that was just as well suited in principle to motorcycle use as it was to the bicycle, though applied in a slightly different manner. In bicycle service, it is provided to give the rider an opportunity to stop pedaling on down grades or smooth roads with favoring winds, and yet permits him to keep control of the bicycle, because a slight back pedal action applied a brake to the wheel.

On a motor-propelled cycle the motor does the driving normally, and the pedals are only brought in action when it is desired to propel the machine by foot power to start the motor. As soon as the engine starts, the coasting feature comes into play, and the action is just the same as though the rider of a foot-propelled cycle was taking advantage of down grade. The pedals provide a rest for the feet, and the back pedaling or reverse pressure begins to bring the brake in action any time it is necessary to retard the speed of the machine.

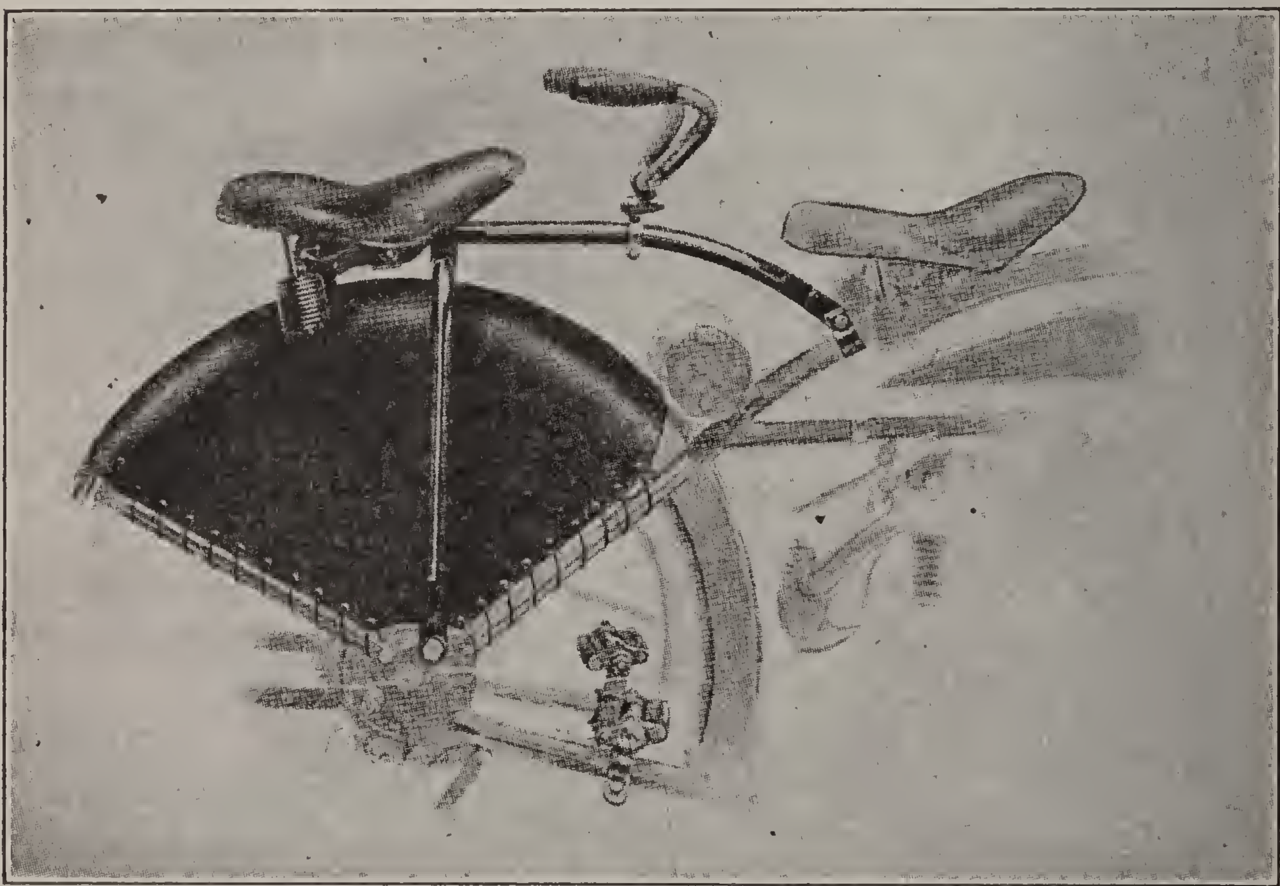


Fig. 245.—Application of Tandem Attachment on Henderson Motorcycles.

The rear sprocket of a chain-drive machine is attached directly to the hub shell; the belt pulley, if that system of transmission is used, can be secured to wheel rim or to hub shell, as desired. The only difference in principle between a coaster hub intended for motorcycle work and the similar device made for bicycles is that two methods of driving the rear wheel are provided, one by mechanical power to a member rigidly secured to the hub shell, the other by foot power through the medium of a friction clutch that automatically engages the hub shell interior as soon as the pedals are pushed forward.

Requirements of Pedal Drive Mechanism.—The requirements of the pedal drive mechanism are well known at the present time, and that employed has demonstrated its correctness in theory and practical application by years of actual use in millions of bicycles. The basic principle of the spirally threaded member and laterally shiftable connector to drive the hub, declutch to provide a free wheel and to apply the brake by further movement has been developed in this country to a state of practical perfection. The best argument in favor of this pedal drive mechanism is that a simple and successful coaster brake cannot be built without incorporating this system, and that all devices on the market embody this principle. The construction is such that the hub is driven smoothly and positively whenever the pedals are rotated forward, the hub is free to rotate independently of the pedal drive sprocket as soon as the feet cease rotating and a reverse motion of the pedals or back pedaling action will apply the brake without slipping. Coaster brakes have been made with ratchets, ball or roll clutches, etc., but these have not been as successful, reliable or enduring as the double taper cone principle of driving and brake actuation universally applied.

What Brake End Should Do.—While the requirements of the pedal drive mechanism were well understood, the principles making for efficient brake action of motorcycle hubs were not realized so completely, and it is on this portion of the mechanism that most manufacturers disagree. To begin with, the essential requirement is that the brake member be capable of retarding the cycle velocity to any degree from a simple and momentary slowing down to a quick, emergency stop. This condition is not hard to meet, almost any form of brake will do it, when new, clean and in proper adjustment. The successful and really practical brake must be one that will provide this essential prompt braking action but it must do it in a gradual manner, because a harsh acting brake will impose injurious stresses in the entire mechanism of brake and related wheel and frame parts. The practical brake should be a form that will not need constant adjustment, the essential mechanism should be thoroughly protected from the abrading influence of road dirt, the brake member should be housed in and supported in a manner that will preclude liability of rattling. The brake parts should be of material that will not only

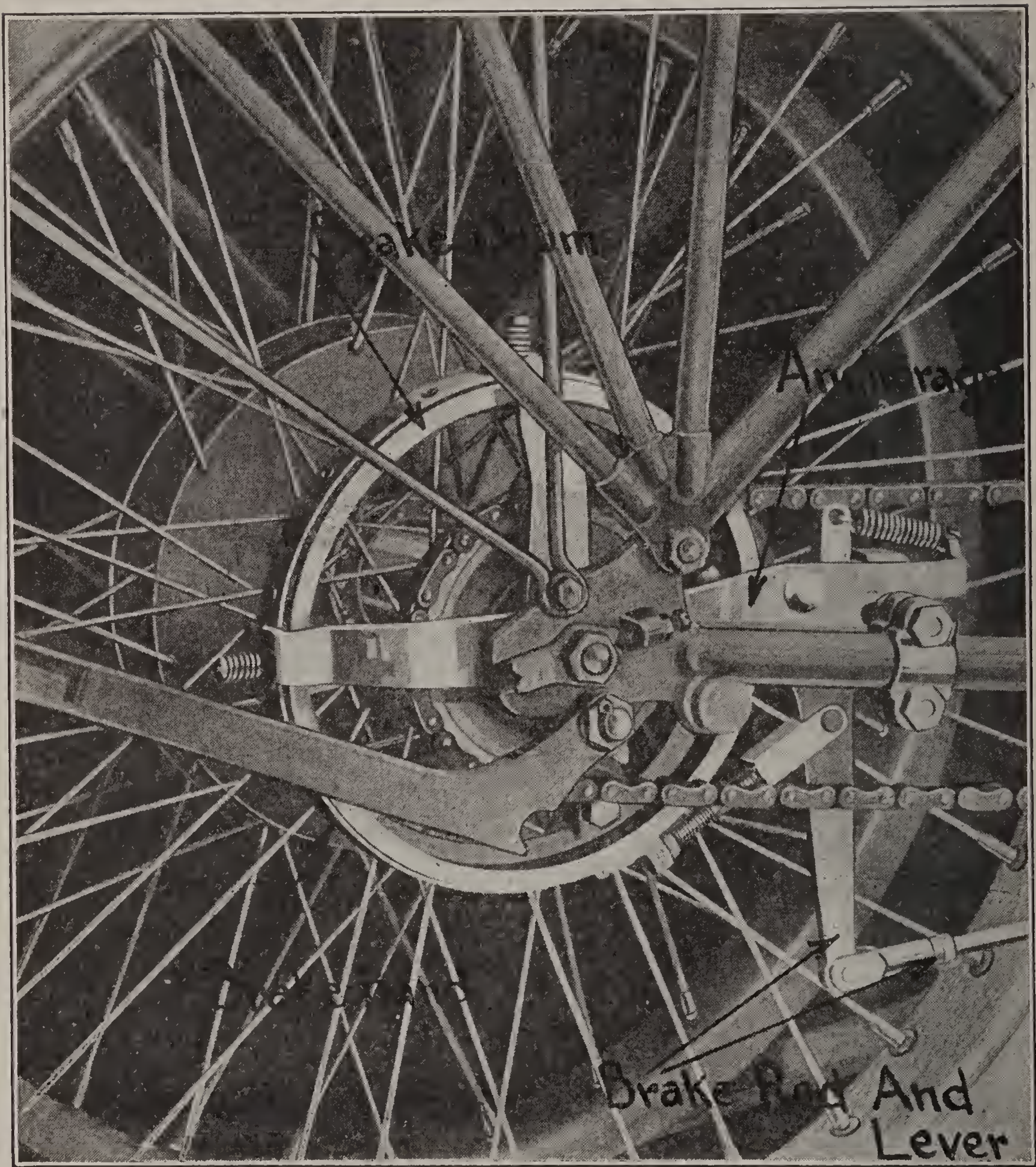


Fig. 246.—External Constricting Band Brake Used on Harley-Davidson Belt Drive Model.

have a high degree of resistance to wear in service, but the members that come in contact to provide the braking action should also have a high degree of frictional adhesion because it is the absorption of power by the frictional contact that retards the momentum of the machine. The design of the brake end should be such that the parts will not drag or tend to engage each other when the brake is released, and the arrangement of braking members should be such as to provide

immediate cessation of braking effort as soon as the pressure exerted by the rider on the actuating members ceases.

While the brake should be easy to apply so the maximum braking effect will be obtained without too much effort on the part of the rider, at the same time, the brake should not be so sensitive that it can be applied inadvertently through unconscious back pedaling. The ability of the brake end to function properly even though flooded with the oil or grease used in lubricating the hub bearings and interior mechanism is also essential.

Let us carefully consider the force needed to afford positive control of the modern motorcycle, then become familiar with the principle of braking action, and a careful analysis of the construction of various types of brakes will permit the rider to form his own conclusions regarding the type that best meets all of the requirements previously enumerated.

Force Required at Brake.—The most any brake can do is to skid the wheel to which it is applied. If it can accomplish this, it is adequate to cope with any of the normal operating conditions. The amount of force needed to lock the wheel depends upon the amount of the total weight of the machine supported by the wheel to which the braking effort is applied, and the relative diameters of wheel and brake member. Much less force will be needed to stop a wheel if the brake is applied near the tire than if it acts near the axle. Structural limitations make it necessary to locate the brake in the hub so it can be actuated positively by back pedaling mechanism that will be entirely protected and properly lubricated but at the same time it is possible to follow automobile practice and provide a drum for the brake to act against that will be of such diameter that the wheel may be controlled without too much exertion on the part of the rider, or producing undue stress on the brake members.

Assume that the machine we are to stop is a powerful twin weighing 250 pounds with tandem attachment and carrying a passenger load of 300 pounds, that being the weight of two average riders. This makes a total of 550 pounds, and we can justly assume that 450 pounds will be supported by the rear wheel. The amount of adhesion between the tire and the ground is generally taken as 60 per cent of the weight on the wheel, so we will have traction enough so a retarding

force must be applied at the brake drum equivalent to the adhesive force of 270 pounds at point of contact between wheel tire and the ground. If the wheel is 28 inches in diameter, it will have a radius of 14 inches. The moment at the axle center due to the leverage factor would be the adhesive pressure times wheel radius which would give a value of 3,780 inch pounds at 1 inch from wheel center. If the brake had an effective diameter of but 3 inches, as would be the case if it was carried in the hub shell, we would be forced to apply a retarding effect of 2,520 pounds to lock the wheel. With a brake drum 6 inches in diameter, it would take only 1,260 pounds retarding

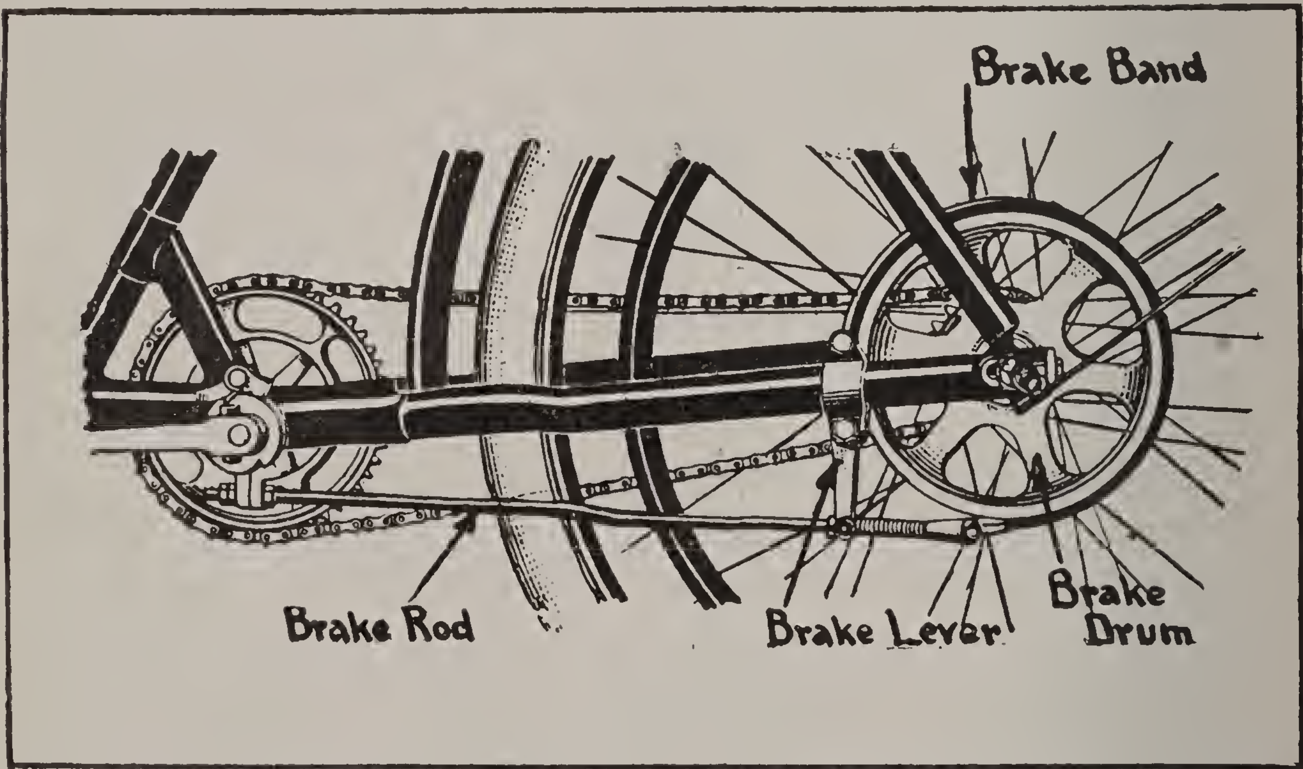


Fig. 247.—Application of Band Brake Actuated by Back Pedaling Ratchet Mechanism.

force to skid the wheel. If a brake block was applied directly to the tire, it would take but 270 pounds adhesive force, or the same amount as maintains traction, to stop the driving member.

It will be apparent that the larger diameter brake members require less effort to stop the wheel than those forms in which the braking effect is exerted near the axle. This use of a large brake drum not only makes for easier brake operation on the part of the rider but conduces to longer life of the parts because of the lessened stresses on the brake anchorage members and also lower unit stress on the materials in contact. While it is very desirable to have a compact

brake assembly, still it is more important to use the requisite proportions that will insure positive braking under all conditions even if compactness and lightness are sacrificed by making the brake drum and brake shoes of adequate diameter, and all parts heavy enough so they will have an ample margin of safety over the actual requirements. Where human life and safety are concerned, it is best to err on the safe side, and the addition of a few ounces of metal is sometimes all that is needed to make a part of doubtful strength one with a large enough margin to guard against the weakening influence of hidden flaws or insure against breakage when subjected to abnormal stress. At the other hand, the brake parts require careful designing to keep the weight down and retain strength, and materials of construction must be selected intelligently to insure absolute reliability and endurance.

Principle of Brake Action.—The friction form of brake is that generally applied to all forms of vehicles. The principle of action may be concisely expressed by saying that if a fixed member is brought to bear against a rotating one, the friction between them will bring the one in motion to a stop. The time needed to stop a rotating body depends entirely upon the amount of friction present between the braking members. This in turn depends upon the co-efficient of friction existing, which varies with the nature of the materials in contact, the effective diameter of the brake members and the pressure holding the parts together. We have seen why large diameters are more desirable than small ones.

The amount of surface in the brake is not as important as effective diameter, because the braking effort depends primarily upon the diameter of the surfaces rather than their width. For example, there would be no difference in braking efficiency as relates to retarding power between a brake band ¼ inch wide or 2 inches wide if the diameter was the same. The wider brake band would provide an important advantage of having greater life because the braking pressure would be distributed over a larger area. It would not be any more effective as a brake, however, than the narrower member. It is generally believed that braking power depends upon the surface in contact, but this is not true. A brake of small diameter might have three times the surface of one of twice the diameter, yet the one with

lesser surface would be twice as effective as a brake. The capable designer will always endeavor to provide surface enough to prevent undue depreciation, and will employ materials in contact that will have a high degree of resistance to deformation. In some forms of brakes, however, the large amount of surface provided is an actual detriment to efficient brake action and serves no useful purpose.

The materials employed for brakes depend largely upon the design, and in every case these should be chosen with two considerations in mind, the most important being the endurance of the material and ability to keep its shape under pressure as well as high degree of resistance to abrasion. The material should not be affected by the heat generated when the brake is used, nor should it become decomposed or its efficiency reduced materially by oil deposits. Another consideration, but one of secondary importance, if it calls for the sacrifice of the qualities previously enumerated, is to employ substances having a high degree of frictional adhesion.

Friction Co-efficient of Various Materials.—In brake design, engineers must seek to increase friction, whereas in bearing construction every effort is made to reduce it. The following brief notes on the characteristics of friction and a definition of the meaning of friction co-efficient will permit even the reader not thoroughly posted on mechanical subjects to understand clearly what is meant when the terms are used.

Friction acts on all matter in motion, and is present as a retarding influence that requires expenditure of power to overcome. As a rule, augmenting the pressure will increase the friction, while lessening the load will reduce it. Friction increases with the roughness of surfaces in contact and decreases as they become smoother. Friction tends to bring everything in motion to a state of rest, and, in so doing, mechanical energy is converted into heat which is dissipated and lost.

A simple experiment to show what coefficient of friction means can be made by anyone. This consists of drawing a block of iron or other metal across a wood table top by means of weights suspended by a cord passing over a pulley at the edge of the table, and then attached to the block, in order to avoid a sharp bend and eliminate lost energy as much as possible. Assuming the block is smooth, also the surface of the table, the first trial can be made with the surfaces absolutely

dry. Weights are added to the cord until enough have been placed thereon to move the block on the table. The weight required to move the block divided by the weight of the block will equal the coefficient of friction for these surfaces. If the block of metal weighs 50 pounds, and the amount of weight necessary to move it is 25 pounds, the coefficient of friction is 25 divided by 50, or 0.50. If the surface of the table is greased with tallow, and the under surface of the block covered with oil, it will be found that considerably less weight will be needed to move the block, proving that the friction has been reduced by lubrication.

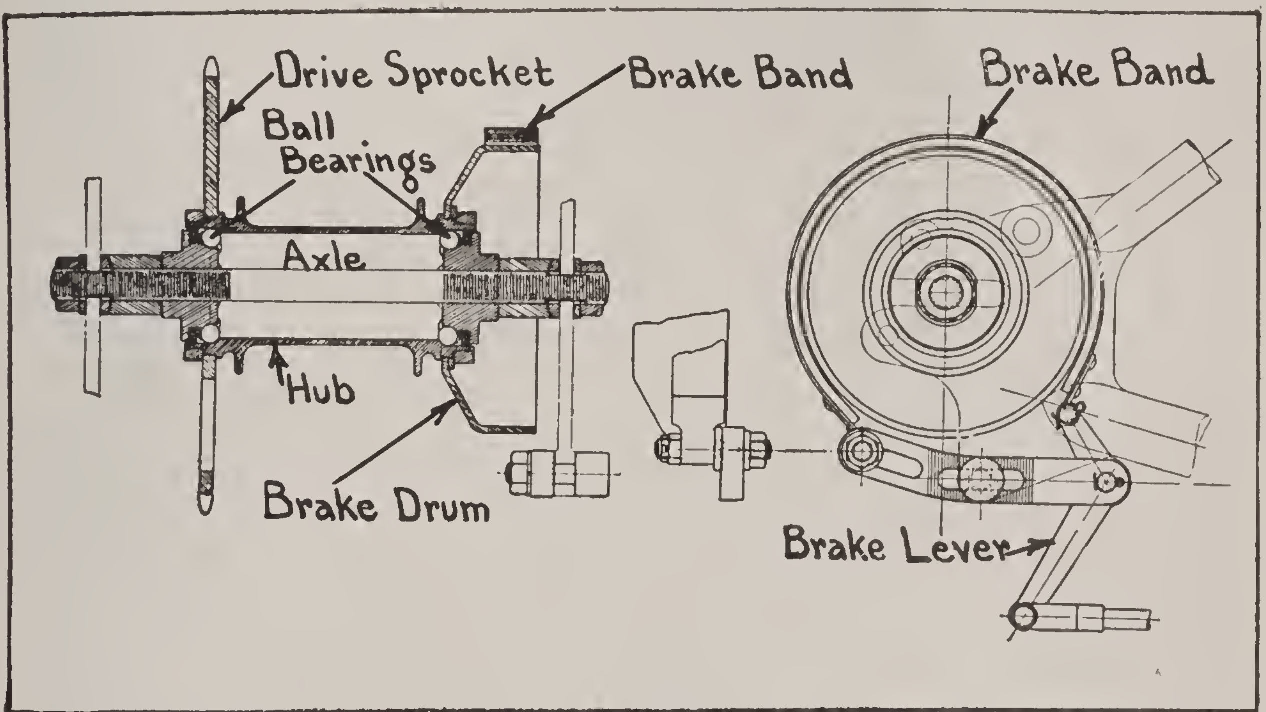


Fig. 248.—External Constricting Band Brake Used on Henderson Motorcycles.

This explains why it is desirable to lubricate bearings, whereas on first thought it would seem that the best braking effort would occur between perfectly dry materials. It would also appear that the softer and rougher materials which have greater friction would be better for brake construction than hard and smooth ones. This would be true if braking effect was all that was to be looked for, and if the factors of gradual application of retarding force and endurance of brake members could be disregarded. As it is important that depreciation be reduced to a minimum, and that all shock should be avoided when braking, one can see a logical reason for the use of

materials that would have less friction adhesion though greater resistance to wear, and which provide smoother brake action.

The materials ordinarily used for brakes and their friction coefficients follow:

Asbestos Fabric on Dry Metal	0.30
Asbestos Fabric on Oily Metal	0.12
Metal to Dry Metal	0.15
Metal to Oily Metal	0.07

These values mean that if an asbestos fabric block or band bears against a dry metal drum, less than one-third or 30 per cent of the pressure maintaining the parts in engagement will be available for stopping brake drum rotation. If the asbestos fabric works against an oily surface, the frictional adhesion or braking force is reduced to but one-eighth of the pressure keeping the parts together.

Asbestos fabric is a soft, yielding material that is very effective if used as an external brake, but it is entirely unsuited for use where much oil is present. While it provides a gradual braking action, it is not capable of withstanding as high unit pressures as metal, so a larger surface must be provided to insure against untimely depreciation. As it is a rough-surfaced material that depreciates as used, constant adjustment and renewal will be necessary to keep the brake in a satisfactory condition. For this reason, this material is better adapted to external constricting band brakes than to other forms, because it can be easily reached for adjustment, and it will be free from oil deposits.

A metal is always used as one brake member, usually the rotating one, and sometimes it is used for both members, fixed as well as movable. While metal does not possess as much friction as the asbestos fabrics, it does not depreciate through action of oil, and it can be used with higher unit pressures than the softer fabric. The surface need not be so great if the metals are properly selected. When used in motorcycle brakes, the revolving metal drum is usually harder than the fixed shoes or retarding members, and in all cases efforts are made to use different metals in combination such as bronze against steel. The metals are much more enduring if lubricated, and the oil film serves to cushion the shock of braking by providing gradual applica-

tion, as well as reducing the liability of dragging or heating, when brake members are released, should there be slight frictional contact between them. Metal brake shoes or discs are therefore better suited for internal brakes than asbestos fabric faced bands, if there is as much oil present as exists in motorcycle hubs.

Leading Types of Brakes.—The most common forms of brake are the various band or shoe types, and the braking members may act against either the inner or outer drum peripheries. The external

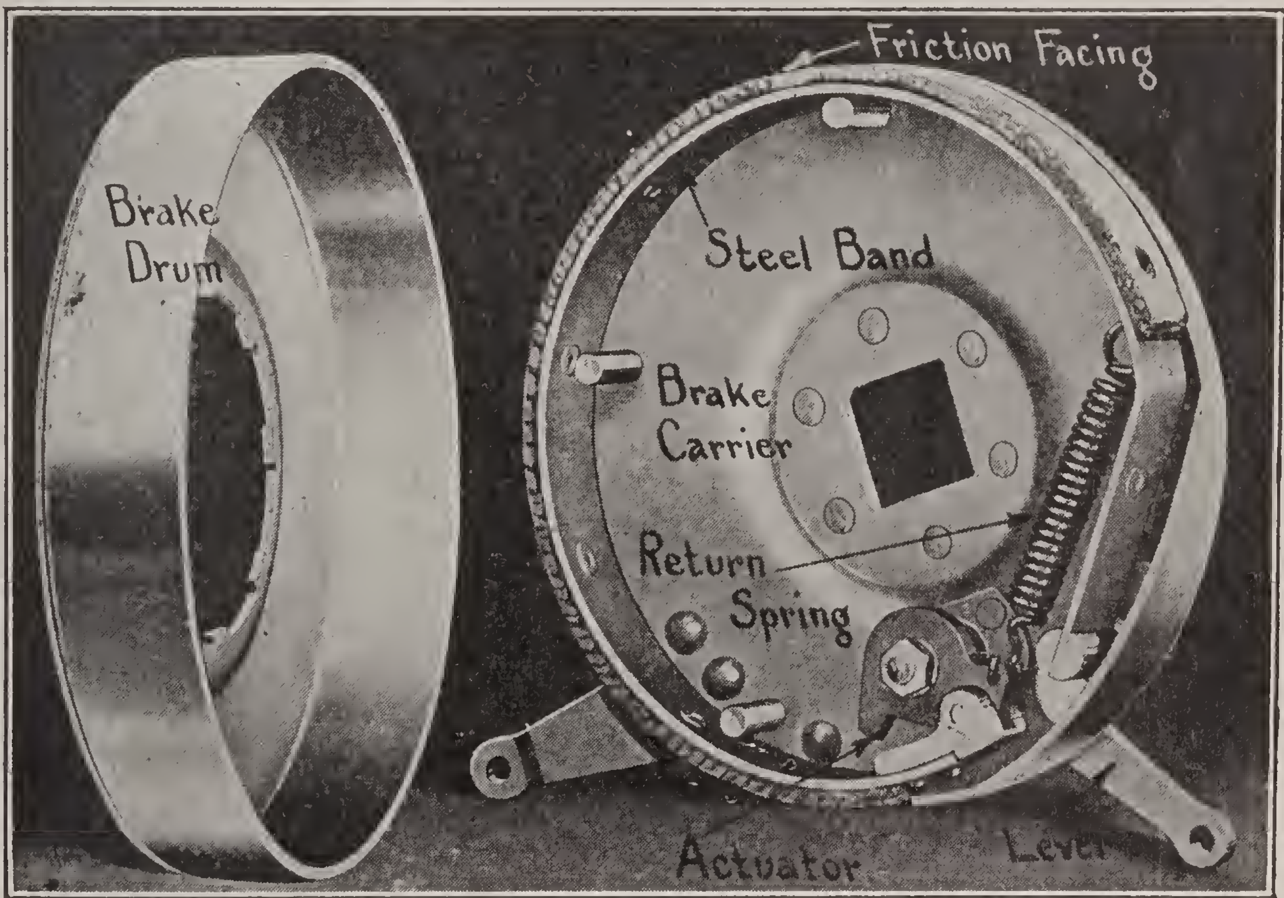


Fig. 249.—Internal Expanding Brake Used on Chain Driven Harley-Davidson Models.

band forms, shown at Figs. 246 to 248 inclusive, tighten around the drum, the internal form as Fig. 249 expands inside the drum or hub shell. There is still another form of external brake in which a friction block bears against the wheel rim or the belt pulley when that method of driving is employed. The external band is usually a flat steel strip faced with asbestos fabric which is sometimes made wedge shaped (Fig. 250) where it fits into the brake drum to provide greater frictional adhesion. The wedge-shape band offers an important advantage, in that it provides a positive grip, but it has an equally great

disadvantage in that it is apt to engage too suddenly, and then again it may wedge in place so tightly that the spring provided to release it will not be effective, and it must be pried out of the V-groove in brake drum. The flat band provides more gradual braking, and if made of proper diameter is amply effective.

The brake block form shown at Fig. 252 has the fault that it cannot be easily operated through the pedals, or incorporated as a part of the hub. It is a separate attachment that is used in this country only for emergency brake service, being controlled by a separate pedal distinct from those utilized in driving the hub. The external brakes have a great disadvantage, inasmuch as they are exposed to dirt, and collect this matter which acts as an abrasive that promotes wear of friction material and drum. They are also liable to become loose and rattle, and they all have more small parts than the simple internal shoe forms. While these external brakes are good, they are not ideal by any means, and if only one brake member is fitted this should be preferably of the internal form. A combination of two brakes, one internal and one external, is provided on some machines, as shown at Fig. 251.

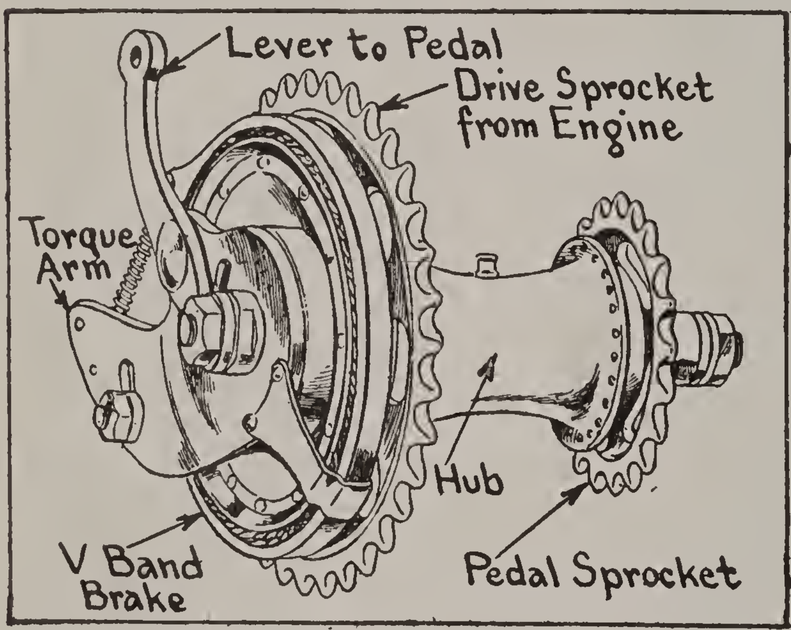


Fig. 250.—The Corbin V Band External Contracting Brake.

The internal brakes are offered in three classifications. The form using a pair of shoes expanded in a drum by a cam is the most popular. The internal ring form, in which the fixed member acts against the inside of the hub shell, is at a disadvantage on account of its small diameter and the great wear due to the excessive pressure necessary to have it grip the hub shell interior with sufficient force to stop the wheel positively. These also are a form that will not release promptly at all times, and are likely to stick if applied too suddenly.

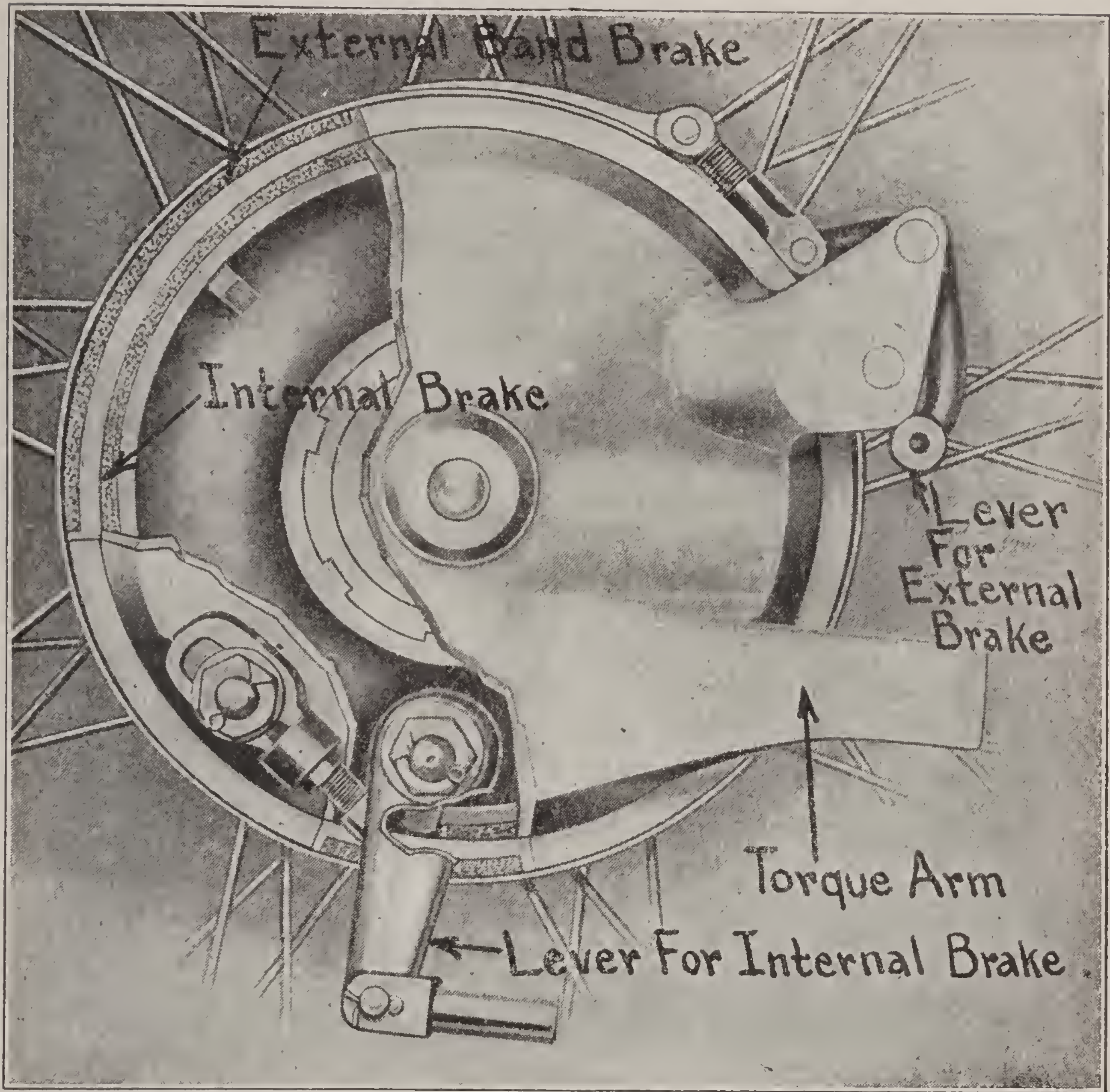


Fig. 251.—Double Brake Combination Used on Indian Two Speed Motorcycles.

The multiple disc brake (Fig. 255) is a form in which a large number of braking members are used, one-half being rotatable with the hub shell, the others being fixed to the axle. Suitable mechanism is interposed between the pedals and discs so the brake elements are brought together with considerable degree of pressure. This form of brake, if copiously lubricated, will provide smooth brake application, and also offers a large amount of frictional surface. It has the disadvantage of not always releasing promptly, because as the oil is squeezed from between the discs by the braking pressure, the plates tend to adhere together when pressure is released because of the partial vacuum

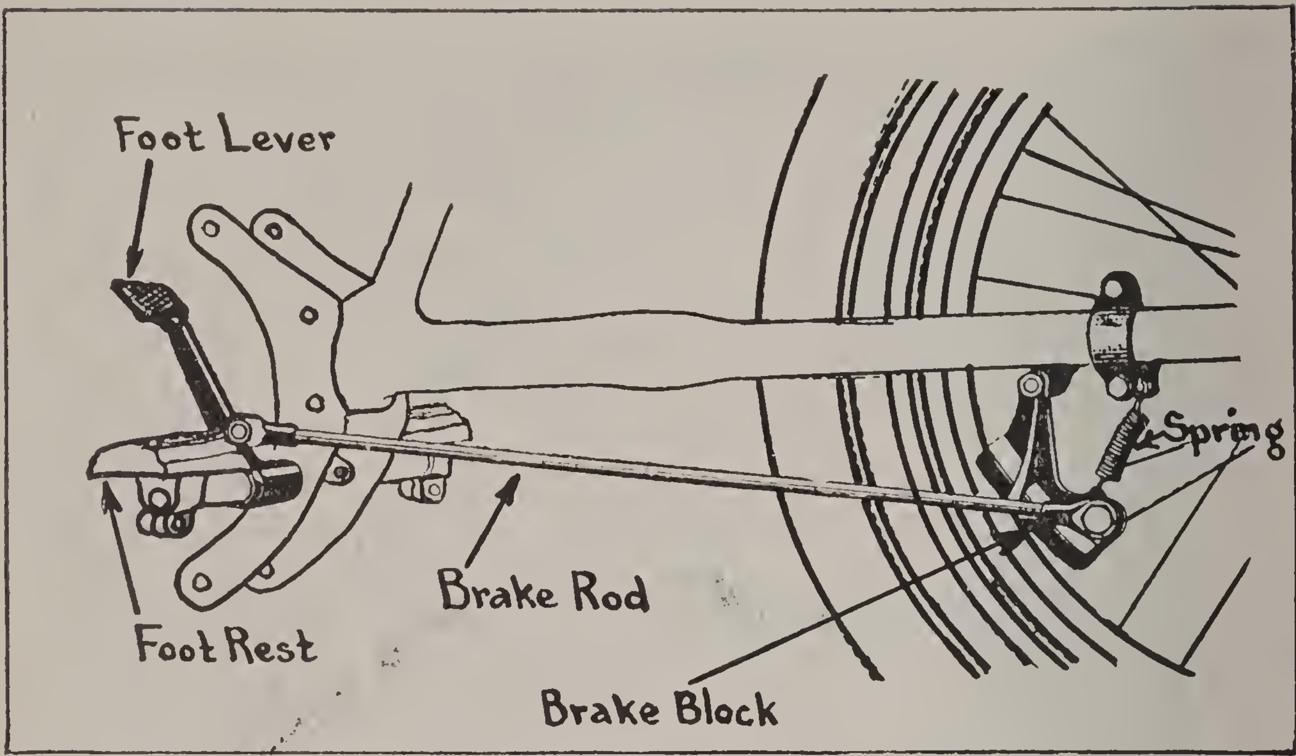


Fig. 252.—Application of Foot Actuated Brake Block to Belt Pulley Rim.

existing between them. If lubrication is neglected, or if the brake is used for long periods, as in mountainous sections, there will be sufficient heat generated by the braking friction to cut or roughen the discs, and even to actually deform them. Under such conditions, the brake becomes harsh in action, no matter how much oil is used, and will also drag even when released because the rough surfaces have

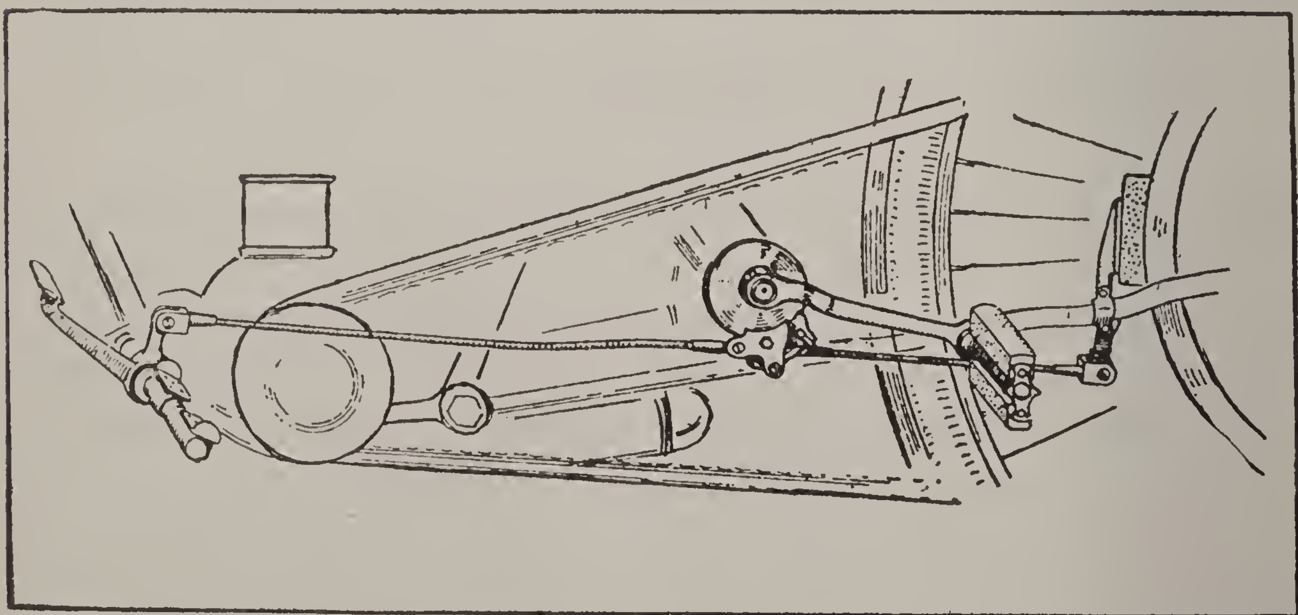


Fig. 253.—Block Brake Fitted for Dual Actuation as Either Pedal at Foot Rest or Back Pedalling Will Apply Brake.

myriads of microscopic projections that tend to interlock as the movable discs revolve by the fixed members.

The internal brake in which bronze shoes of ample size are brought into engagement with a hardened steel drum interior offers a large number of advantages. To enumerate these briefly, we have: First, utmost simplicity; second, strong parts; third, high retarding power; fourth, freedom from dragging; fifth, efficient braking with oil between the surfaces; sixth, gradual or immediate brake application as desired; seventh, all brake parts lubricated and kept clean; eighth, complete

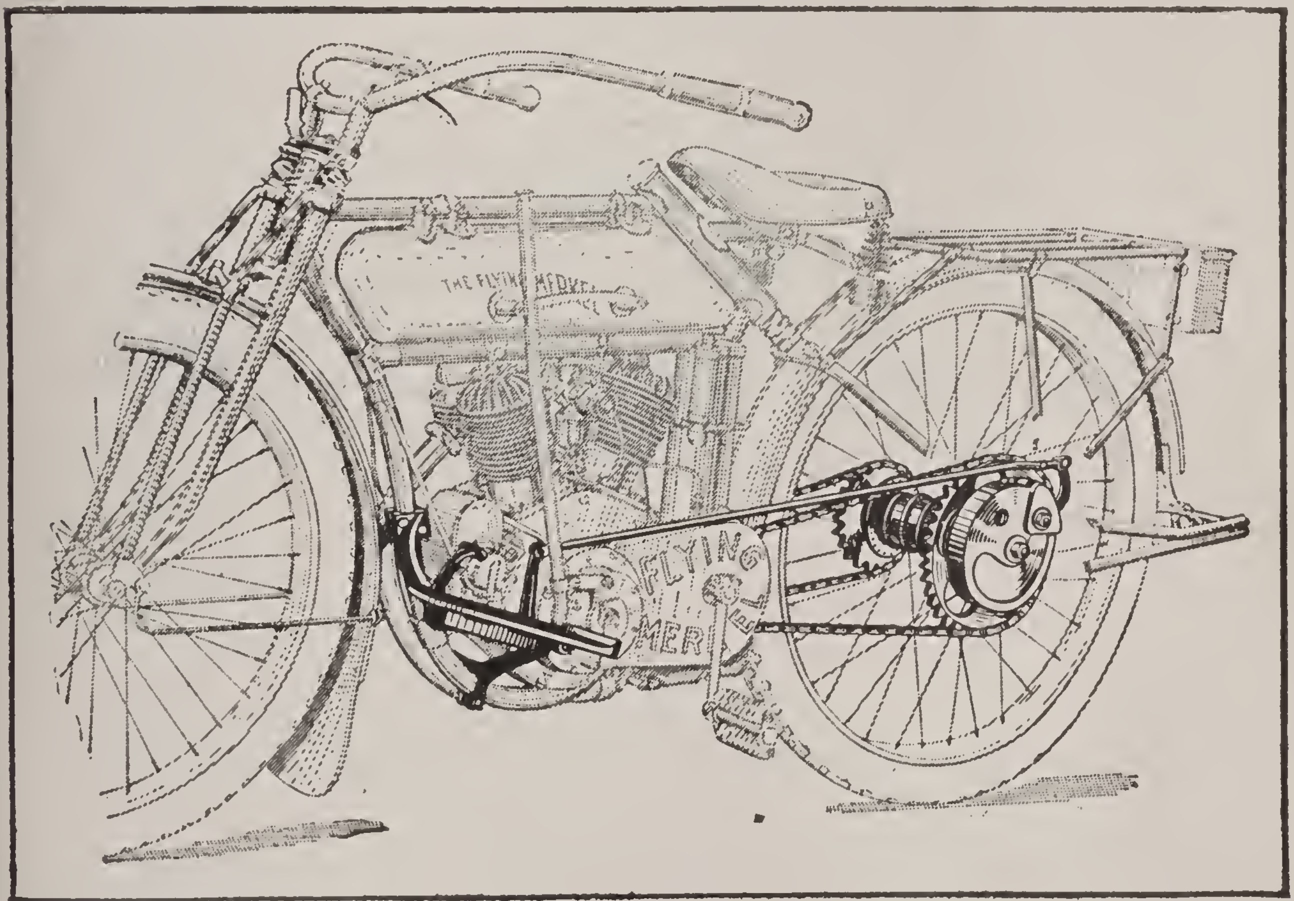


Fig. 254.—Showing the Application of Dual Brake Control on the Flying Merkel Motorcycle.

enclosure of brake members; ninth, absolutely prompt release of brake shoes; tenth, braking force obtained by minimum effort; eleventh, brake actuated directly from pedals by strong, simple mechanism; and twelfth, maximum endurance because of the ability of the bronze shoes to resist wear due to abrasion better than any other material and practical indestructibility of the hardened steel brake drum. This endurance is augmented by the oil always present between brake

surfaces and the lessened strain on the parts, because the oil film absorbs the first shock due to brake application.

Operation of Typical Braking and Coasting Hub.—The New Departure, Model L, has been devised with special reference to the requirements of motorcycle service. As will be evident from inspection of illustration, Fig. 256, the general construction of the pedal drive mechanism follows the well-established practice except that all parts are heavier and stronger than anything devised to date. Beginning with a 5/8 inch diameter axle, the entire mechanism has been

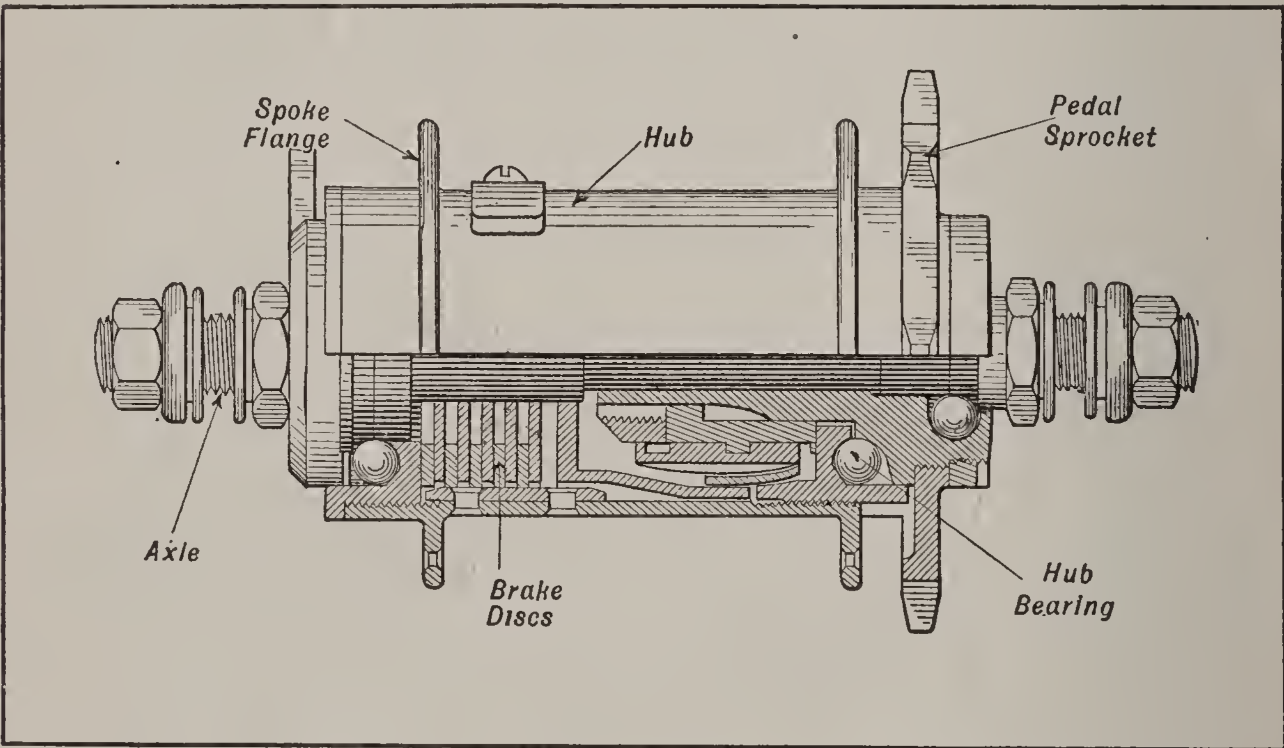


Fig. 255.—Typical Multiple Disc Coasting and Braking Hub.

augmented in size to conform to automobile rules of practice rather than adhering to bicycle construction. The ball bearings are large enough for the wheel of an automobile, and, in addition to the use of large balls, an automobile type or heavy separator is utilized.

Referring to the illustration, we see that the main portion of the device is a hub shell carrying a brake drum and flanges to which the spokes are secured. The outer ball races are formed in the hub shell, which is glass hard at the point where the balls run. The brake drum is a steel stamping 6 inches in diameter, and securely attached to the hub shell flange by a process of electric spot welding, which fuses the members at a number of points to form an intimate bond between

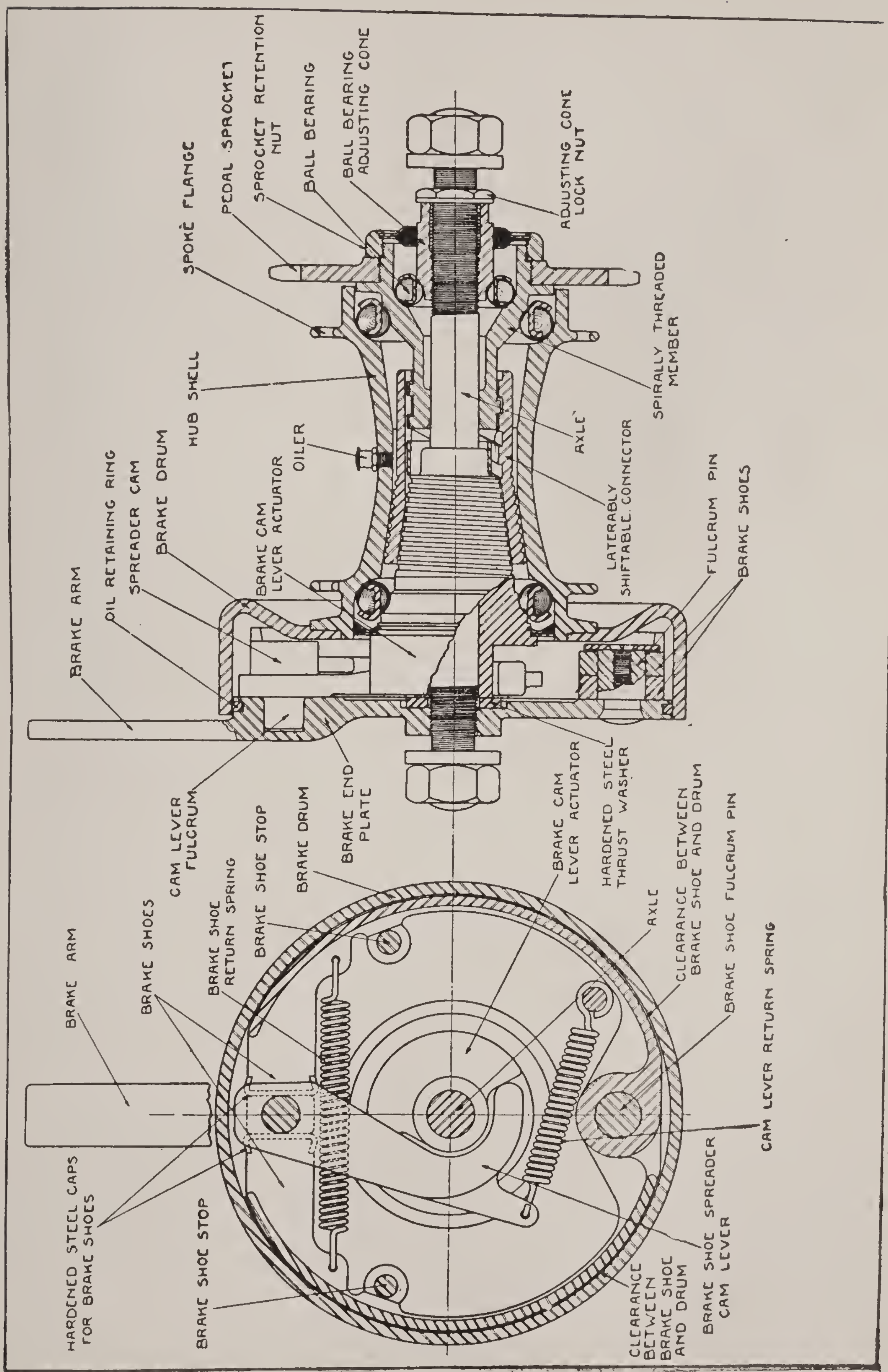


Fig. 256.—Sectional View, Showing Interior Construction of New Departure Model L Coaster Brake.

them. Contrast this to the usual method of riveting or keying such a member in place and it will be apparent that every precaution has been taken to avoid any trouble from loose fastenings. In the chain drive type the sprocket-retaining flange is secured to the brake drum by the same process.

The pedal-chain sprocket is attached to a rotatable member supported on an adjustable ball bearing, and at the inner end the member is provided with a spiral thread. This male thread fits into a corresponding female portion in the laterally shiftable member, and the angle of the thread is such that when the pedal sprocket is rotated forward, the spiral draws the shiftable member against the tapering female clutch member forming part of the hub shell. The clutching action connects the sprocket to the hub and rotates it. If the pedals are held from moving, the clutch releases automatically, and the hub shell can run independently of the foot pedal mechanism. If the foot action is reversed, or the pedal sprocket rotated backward, the female clutch member in the inner portion of the laterally shiftable connector will be forced tightly against the male taper of the brake cam-lever actuator, which can oscillate on the axle only in the direction necessary to apply the brake.

If one refers to sketch of brake end at Fig. 257, it will be seen that the oscillating motion of the actuator transmits a similar motion to the end of the lever of which the brake-shoe spreader cam forms a part. Any displacement of the cam will spread the brake shoes apart, and they will fulcrum on the supporting pin secured to the brake end plate. The brake shoes then take up the clearance existing between their outer surface and the inner surface of the drum, and exert a retarding effect in proportion to the amount of pressure applied by back pedaling.

As soon as the back pedaling pressure is released, the springs serve to bring the brake shoes out of engagement immediately. The upper one holds the brake shoes firmly against the cam, the lower one returns the cam lever back against its stop and also brings the oscillating actuator back in position ready for further brake application when the laterally shiftable member clutches it.

The brake shoes and spreader cam are carried by a drop forged steel plate which has an arm formed integrally that is intended to be

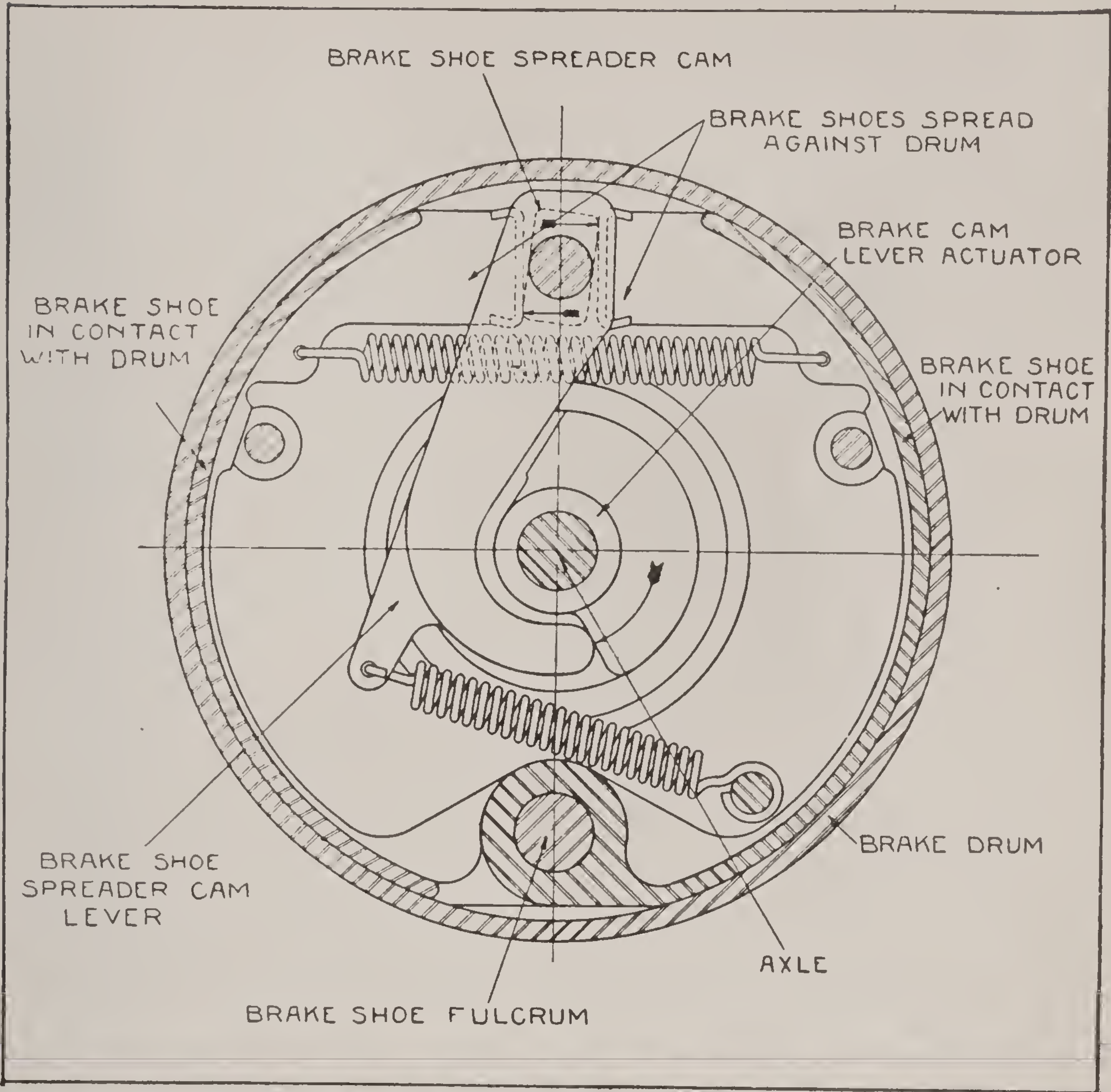


Fig. 257.—Showing Method of Brake Shoe Actuation by Cam Action in Internal Expanding Brake.

attached to the frame members and serve as an anchorage to prevent brake shoe rotation.

How Rider's Effort is Multiplied.—A diagram is presented at Fig. 258 for the benefit of those mechanically disposed, which demonstrates clearly how the pressure of the rider's foot on the pedal is multiplied, and how much pressure is available between brake shoes and drum to stop the wheel. This shows the effectiveness and correct design of the internal brake, and how positive control is obtained with but little effort.

In this case, we have assumed that the total weight of a heavy motorcycle, tandem attachment and two heavy riders is 600 pounds.

The amount of braking force required at wheel rim is equal to 36 per cent of the total weight, or 216 pounds, which represents the adhesion between tire and ground. This is not an extreme case, as the modern motorcycle and two large riders would easily weigh 600 pounds, and a brake must be designed with the abnormal service it may be subjected to in mind rather than the average if it is to be relied on to cope with the unexpected emergency.

Almost any rider can exert a back pedal pressure of 100 pounds. This is applied at the end of a 6-inch pedal crank, and if the front sprocket is 5.4 inches in diameter, a pull of 222 pounds is applied to the chain. This is directed to a sprocket having a radius of 2.2 inches, which is equivalent to a moment of 488-inch pounds at 1 inch from axle center. Owing to the point where the spreader-cam lever end bears against the brake shoes being less than 1 inch from axle center, we have an effective force of 601 pounds at the end of the lever. The difference in length between lever and spreader cam further compounds the pressure, and if we consider all the load concentrated against one brake shoe for simplicity, we find that we have an effective spreading force of 3,606 pounds at the end of the brake shoe. The brake shoe is really a curved lever, so at a point halfway between where the cam bears and the fulcrum pin, we find that it is possible to exert a pressure of 7,165 pounds. All of this is not available for braking, however, because if we consider the coefficient of friction, we will have an effective retarding force of 1,075 pounds at the brake drum, and this, in turn, is equivalent to a retarding force of 230 pounds at contact point of wheel tire and road surface, which is at 14 inches radius, or considerably more than is needed to skid the wheel. If a rider is alone, a back pedaling pressure of about 50 pounds would suffice to lock the wheel. It will be apparent that positive control with minimum exertion on part of the rider is possible, because the initial force is compounded many times by the simple and strong leverage provided. Obviously, the brake force can be varied at will and is entirely within the control of the rider.

Motorcycle Tires.—The single tube tires used on bicycles did not have sufficient resistance to perform satisfactorily on motorcycles, and also had the grave disadvantage of being difficult to repair. The double tube tire which was used to some extent in bicycle practice

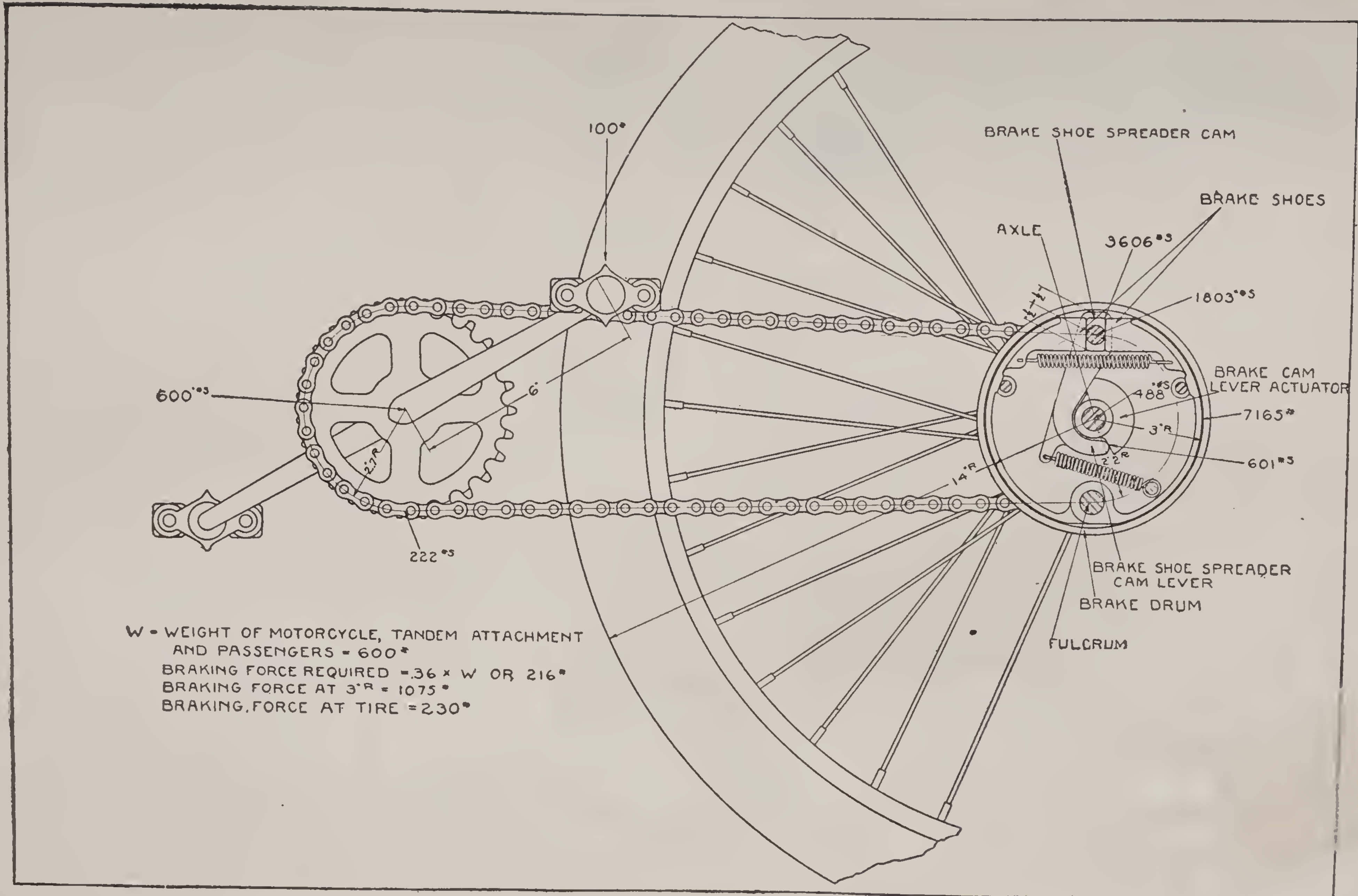


Fig. 258.—Diagram Showing How the Rider's Effort is Multiplied in Obtaining Effective Braking With Cam Actuated Internal Shoe Brake.

was strengthened and made larger, and adapted for the heavier vehicle. This construction consists essentially of two members, an outer casing or shoe, and an inner tube that is depended on to retain the air. The outer casing is attached to the rim in such a way that it may be easily removed to gain access to the inner tube. In event of a small puncture, the patch is applied to the inner tube member, and the outer casing need not receive attention until a more convenient time. A typical outer casing is shown at Fig. 259, A, and it consists essentially of a carcass or body composed of layers of Sea Island cotton fabric impregnated with rubber. A number of plies of this fabric are

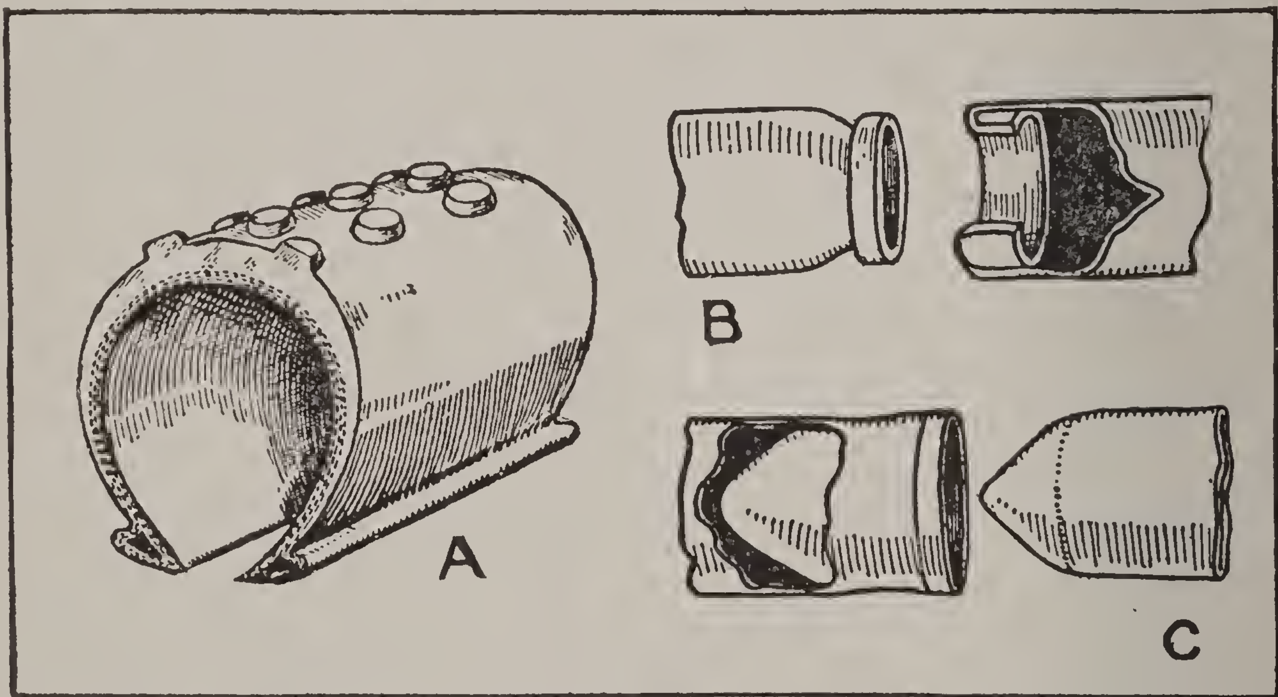


Fig. 259.—Construction of Motorcycle Tire Outer Casing and Inner Tube.

placed around a suitable iron core with vulcanizing cement between each layer, and over these are attached a number of layers of rubber composition that forms the tread of the tires. After being built up, the assembly is placed in a steam heater and vulcanized or cured until it is practically a solid mass. The casing is provided with beads around the inside which are intended to fit into channels in the rim. When the inner tubes are inflated, the beads will be forced tightly into the clincher rim and the tire will be held positively in place. To remove the outer casing, it is necessary to deflate the tire.

The outer or tread portion, which is the part of the tire that is in contact with the road surface, is made of exceptionally tough rubber

compound which is not apt to depreciate rapidly. The inner tube, upon which the resiliency of the tire depends, is composed of practically pure rubber, and is therefore adapted for holding air, though the material of which it is composed is too soft to possess any strength or resistance to abrasion, which must be provided by the outer casings. Inner tubes are made in two forms, the continuous or one-piece type, which is the same as that so generally used on automobiles, and the jointed or butt end form as shown at Fig. 259, B and C. In the former, the joint is made by slipping one end of the tube into the other, and when the tube is inflated the collar member will be forced out tightly against the inner face of the retaining member on the other end, and an air-tight joint will be obtained. In the form shown at C, the inner tube is a closed end form, and has a tapering end that is intended to fit into a corresponding female member at the other. The advantage of the jointed inner tube is that it may be removed from the wheel without taking that member out of the frame which obviously is not possible with a one-piece inner tube. The form shown at B, however, is apt to leak to some extent, and if the jointed inner tube is used, the form shown at C is preferred. The ends of the tube in contact are also apt to chafe and leak.

Side Car Advantages.—While the tandem attachment is an inexpensive solution of the passenger-carrying problem, it is not the most satisfactory because it is not a really practical means of carrying an elderly person or one of the fair sex. The occupant of the tandem attachment may throw a machine out of balance by moving around, and may seriously interfere with the proper control of the machine by the rider, unless very careful and experienced. Then again, it is difficult to carry on a conversation between the motorcycle rider and the tandem passenger, so this device is not as sociable as the side car.

The side car is a simple one-wheel framework that may be readily clamped to the motorcycle, and which carries a seat of comfortable proportions that will provide thorough protection for the passenger. When a side car is used, it is imperative to employ a machine of ample power, and it is necessary to use a two-speed gear to secure proper results when touring. A typical side car attached to a motorcycle is shown at Fig. 260, and it will be apparent that the three-wheel vehicle thus provided is much more sociable than the tandem attachment,

and also much more comfortable for the passenger. Owing to the three-point support, neither the rider nor the passenger need concern themselves with maintaining balance, as it is impossible for the machine to tip over. It costs but very little more to use the side car than it does to ride the machine without this attachment. An important advantage of the side car construction is that this member may be readily removed at such times that the motorcycle alone is to be used.

Fig. 260.—Application of Sidecar to Indian Motorcycle.

Forms of Side Car.—There are two main types of side cars, the rigid and the caster wheel, both forms being shown at Fig. 261. In the rigid wheel type at the top of the illustration, the outboard supporting member revolves on a fixed axle and is capable of only a rotary movement. In the caster wheel form below it, the outboard supporting member is carried in a fork supported by a ball bearing steering head so the wheel may turn automatically in the same

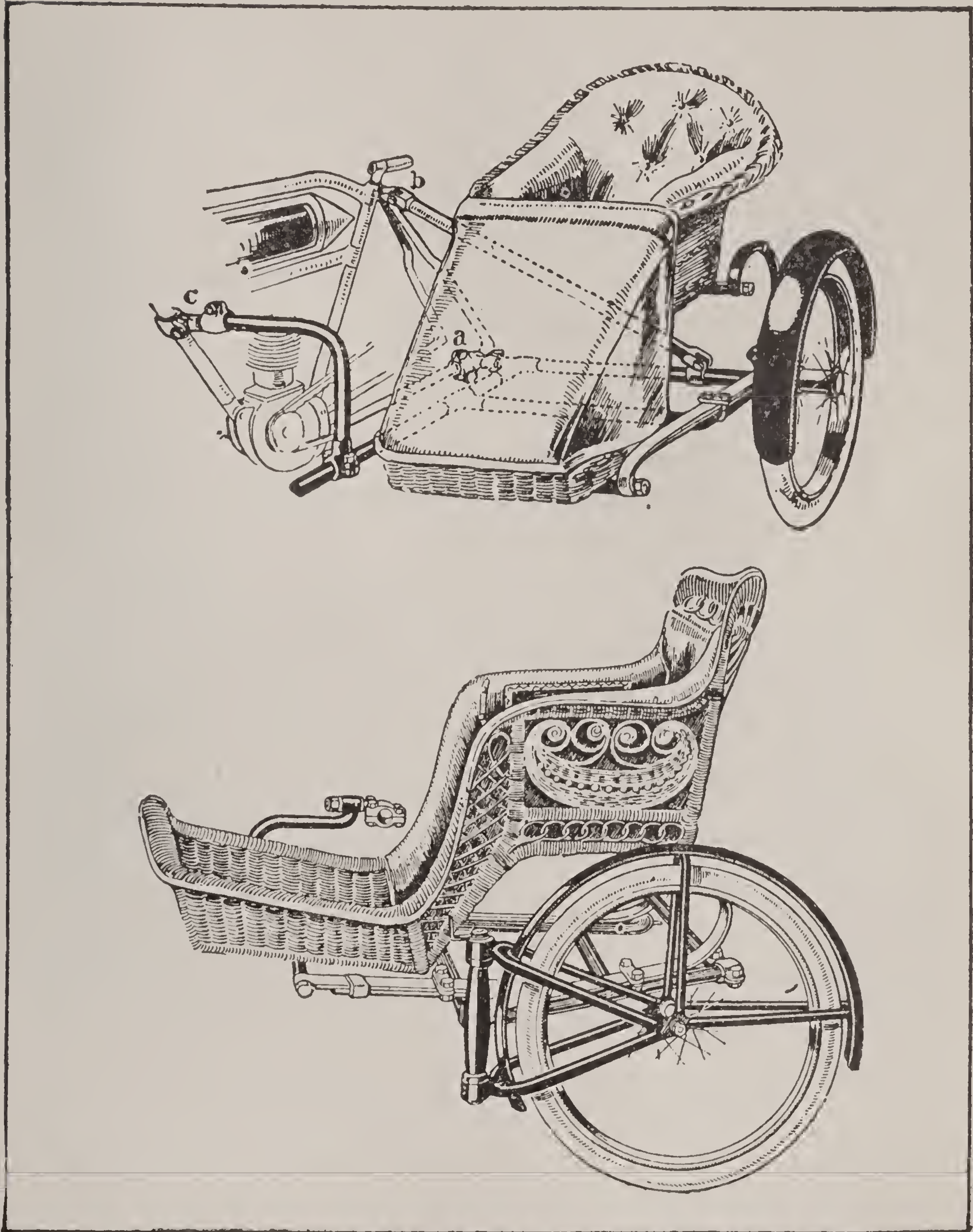


Fig 261.—Examples of Rigid and Castor Wheel Side Cars.

direction as the front wheel of the motorcycle. Experienced users of side cars are inclined to favor the rigid type, as it is claimed it is simpler, and if properly alined with the motorcycle frame there will be but little more wear on the tire than is evidenced in the caster wheel type. The form with the movable wheel is easier to steer

however, owing to the wheel automatically assuming the angle required to describe the curve made when turning corners. A side car of American design which has attracted some attention on account of the novel construction is shown at Fig. 262. This is a flexible form in which it is possible for the rider of the motorcycle to lean when turning corners just as though the side car was not fitted to the motorcycle. The wheel of the side car is carried on an axle spindle supported by a hinged member from which the lever B extends. This is joined with lever A on the other end of the axle by a rod passing through the hollow tube forming the rear frame member. Any in-

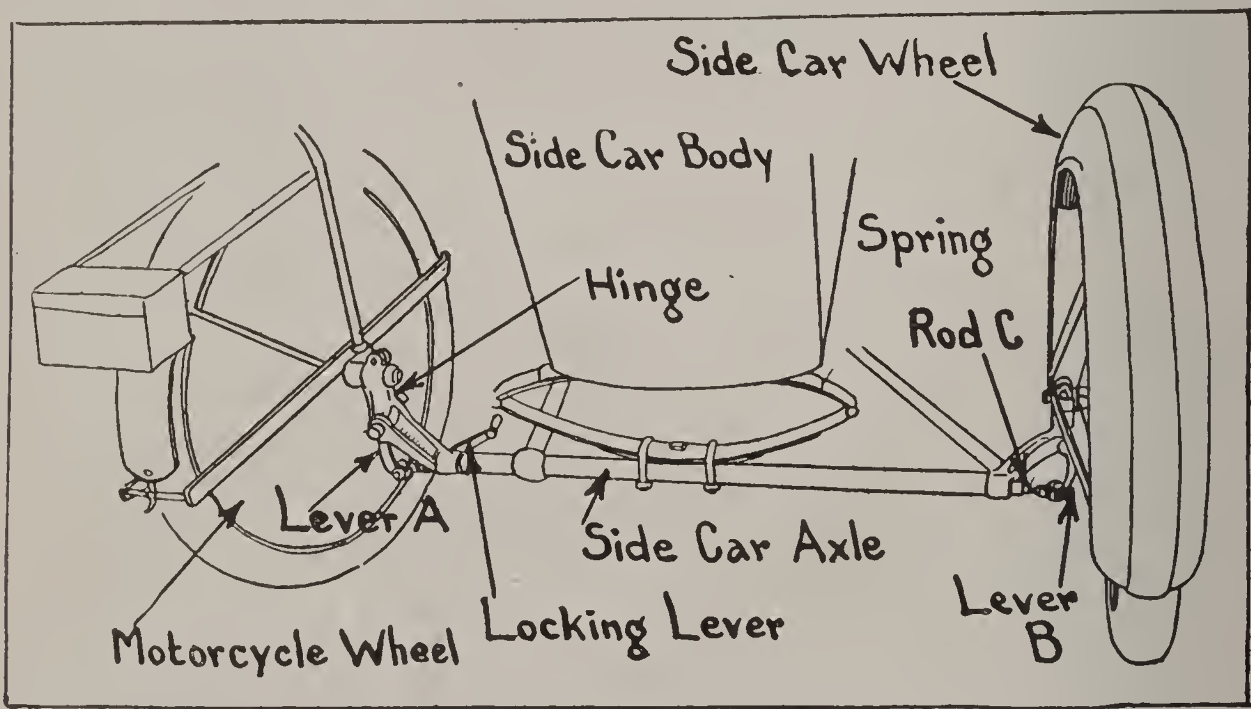


Fig. 262.—Flexible Side Car of American Design.

clination of the motorcycle wheel will produce a corresponding movement of the side car wheel, as lever A controlled by the motorcycle will transmit its motion to lever B that controls the side car wheel. A locking lever is provided so the wheels will remain vertical, and the same effect obtain as with the rigid type side car, if desired. It is claimed that the flexible feature makes the machine easier to steer than the usual rigid type. The side car frame may be fitted with a variety of bodies depending upon the preference of the purchaser, ranging from the simple chair form, shown at Figs. 261 and 263, to the more expensive coach-built body designs, such as shown at Fig. 260.

Side Car Attachment.—The chassis of a typical side car with the body removed is shown at Fig. 264 to outline the method of attachment ordinarily followed. Clamps are provided on the motorcycle frame at two points, one at the front end of the diagonal tube, just below the frame cross bar, and one on the rear fork stay, just a little ahead of the motorcycle rear wheel axle. The front end of the side car chassis is carried by a curved tube extending from the clamp on the frame tube to a similar clamping member at the front end of the side car. A yoke at the end of the side car axle attaches to the clamp at the rear end of the motorcycle, and a cross bar or brace

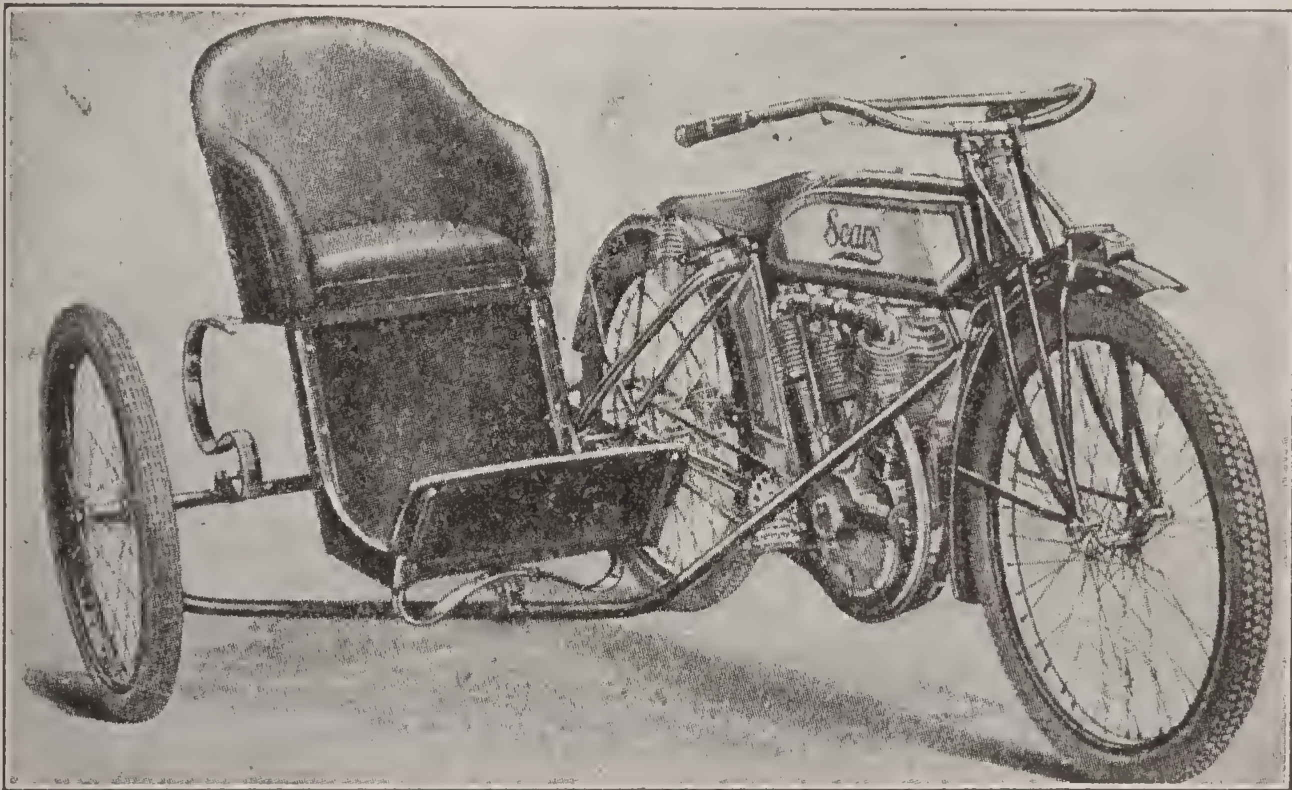


Fig. 263.—Inexpensive Form of Side Car.

extends from the seat post cluster of the motorcycle to a point on the axle of the side car adjacent to the supporting wheel. When the clamps are firmly secured a very stiff and rigid frame structure is obtained, and the motorcycle and its side car attachment are practically one structure.

Considerable care is needed in fitting a side car, because difficulty will be experienced in steering if the wheel of the motorcycle and that of the side car are not in proper alinement. This means that not only the wheel centers must coincide but that the front end of the side

car wheel must be separated from a similar point on the motorcycle wheel by exactly the same amount of space as obtains at the rear end. In other words, the side car wheel must be parallel to the motorcycle wheel and a line drawn through the axle centers of both wheels must also coincide. The method of lining up a side car with a straight edge is shown at Fig. 265, A. If the wheel of a side car is set ahead of that of the motorcycle or if it is not parallel, steering will be very difficult because the wheel will not roll around on an arc of a circle but will move with a combined rolling and sliding motion as indicated by the dotted lines at Fig. 265, B.

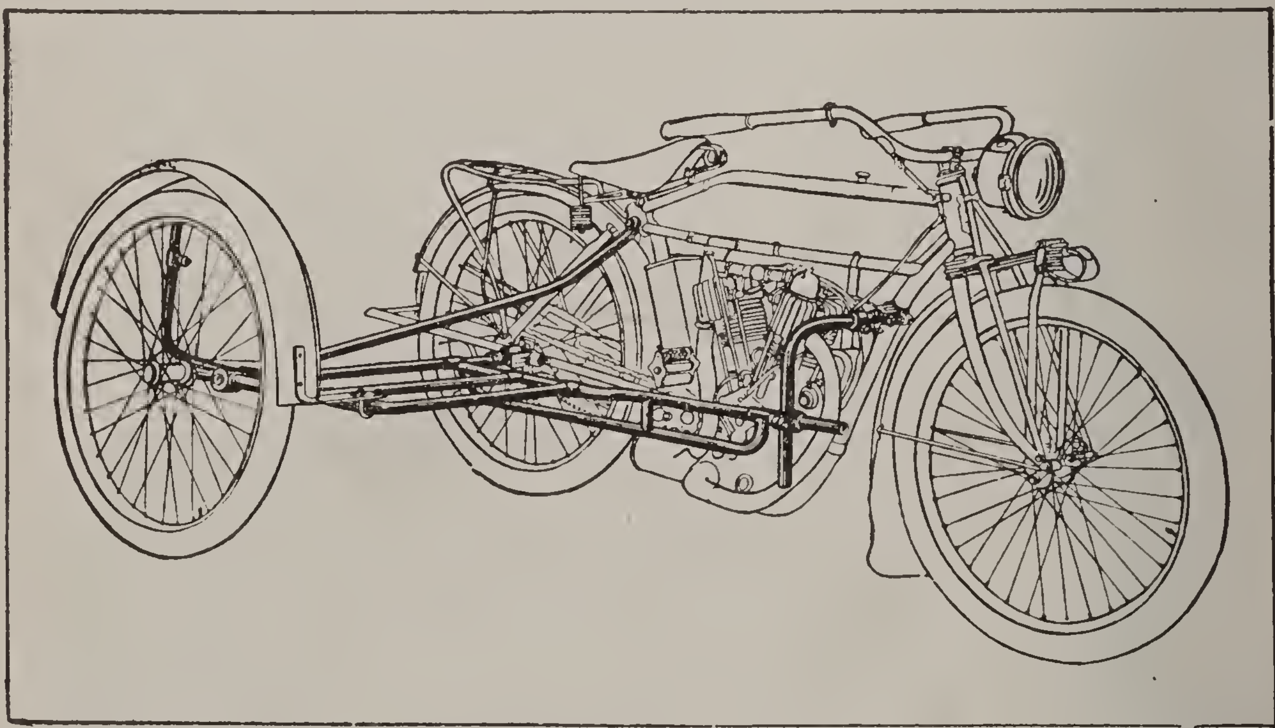


Fig. 264.—Typical Side Car Chassis With Body Removed, Showing Method of Attaching to Standard Motorcycle.

The diagrams presented at C will show a method of side car operation recommended by an English authority in order to secure easier steering. Even if the side car is perfectly lined up, some difficulty may be experienced in steering, though after a rider becomes proficient, it will not be a difficult matter to control the side car combination satisfactorily.

Methods of Starting Motorcycles.—The writer will now describe the common methods of starting motorcycles equipped with two-speed gear, as the accepted method of setting the power plant in motion in a single-geared machine by means of the pedals is generally

understood at this time. The starting crank is a satisfactory means, if a multiple-cylinder engine is used and the crank can be applied to the driving gearing in such a way that the engine will be rotated faster than the starting handle. The starting arrangement used on the Henderson motorcycle, and illustrated at Fig. 266, is a distinctive design, because the handle may be folded out of the way after the engine is started. At A, the crank is shown extended for starting the motor, while at B the crank handle is shown in place in the clip

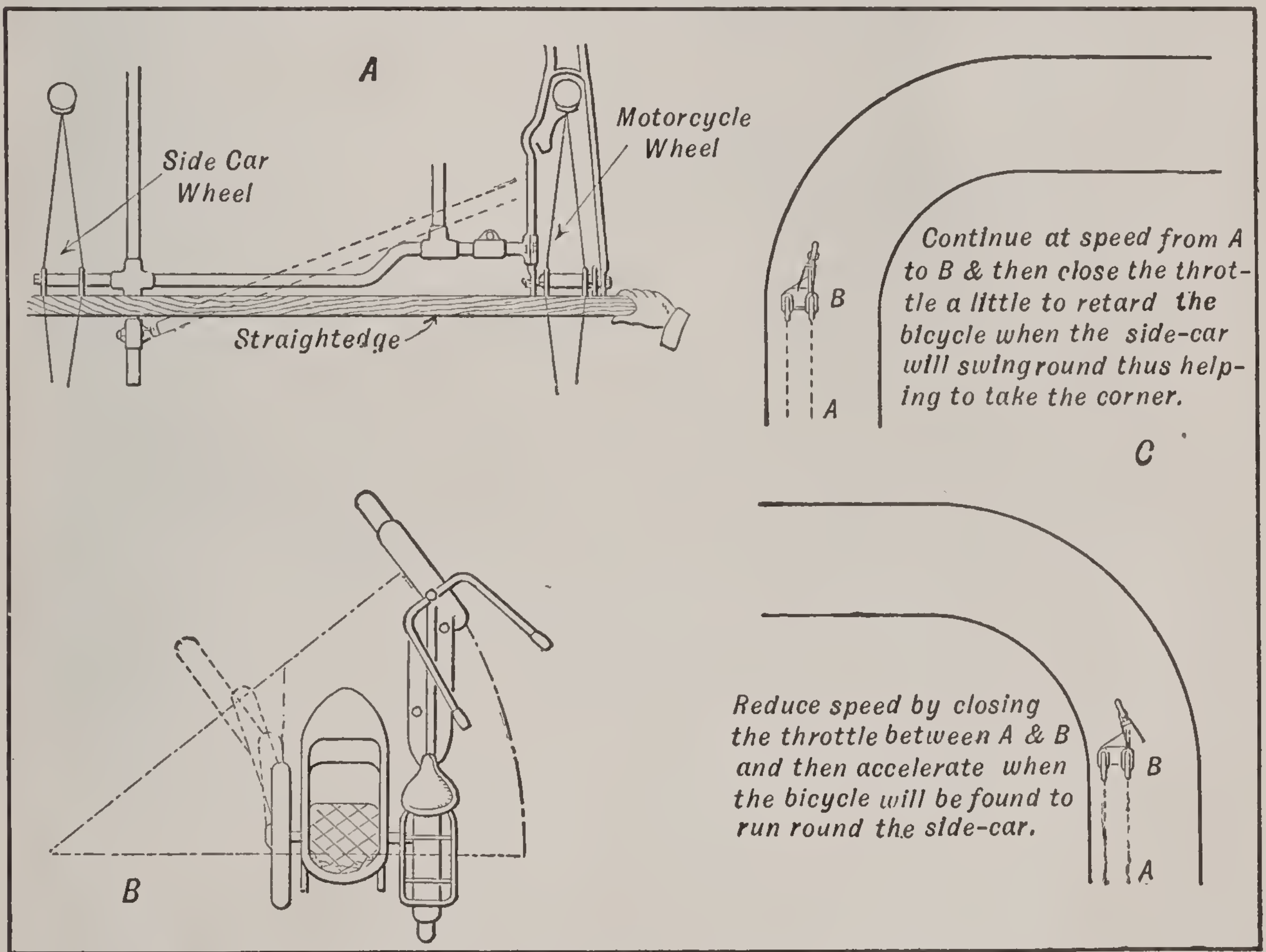


Fig. 265.—Diagram Showing Method of Attaching Side Car and of Controlling Motorcycle and Side Car Combination.

attached to the frame that holds it out of the way when the machine is in use.

A large and near view of the Indian kick starter, which is a thoroughly practical and simple device, is shown at Fig. 267. A large sprocket is mounted on a suitable bearing, and is adapted to be oscillated by a starter pedal carrying a suitable pad member against which foot pressure may be exerted. The large sprocket is joined to

a much smaller starting sprocket that connects with the engine shaft when the pedal is pushed forward and which turns the interior mechanism of the engine fast enough to set the power plant in motion. It is said that the Indian was the first American motorcycle to depart from the conventional pedaling starting system and to introduce the foot starter. A forward thrust of the pedal crank engages the ratchet drive that connects the small starting sprocket to the engine shaft and at the end of the stroke the mechanism releases automatically, and permits the crank to return to its normal position. An automatic mechanism provides positive disconnection from the engine

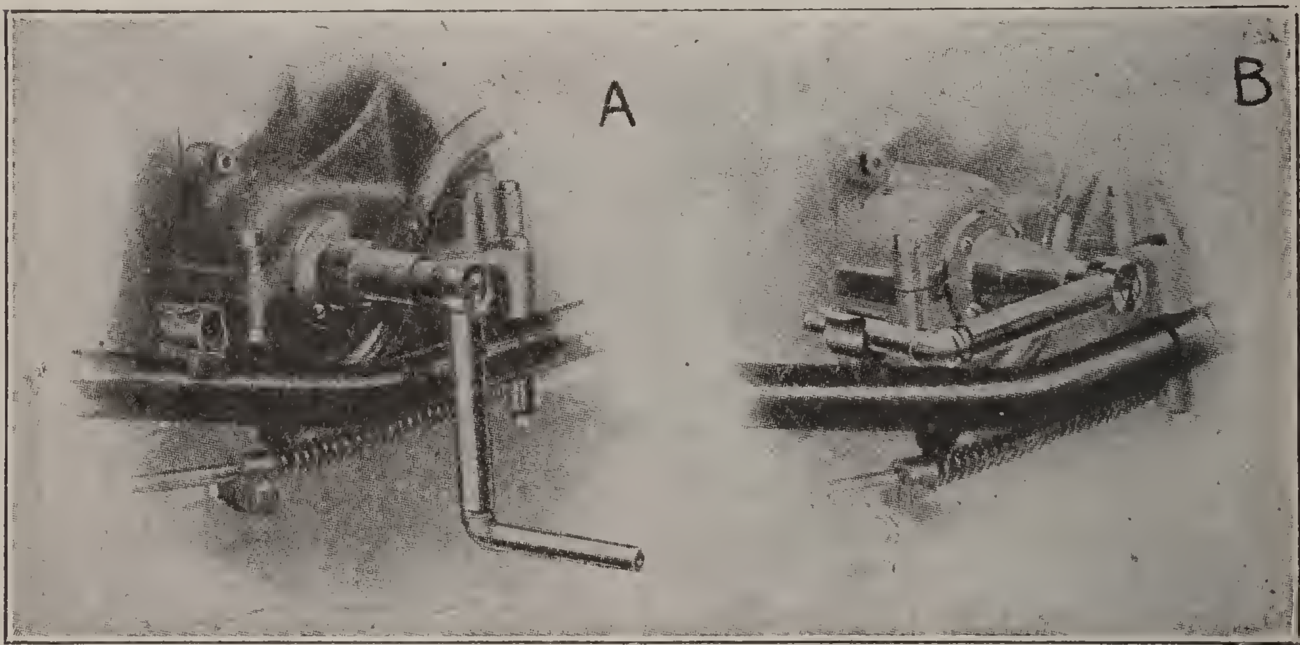


Fig. 266.—Folding Starting Crank Used on Henderson Four Cylinder Motorcycle.

should a back fire occur. The foot rest on the starting crank is hinged and can be folded out of the way when not in operation to allow unobstructed use of the foot board. With the foot starter, prompt starting is facilitated by priming the cylinders with gasoline, particularly when the motor is cold. This operation is made easy on the Indian machines by placing a small syringe or priming gun in the filler opening of the gasoline tank so a small amount of gasoline may be drawn out to fill the priming cups on the cylinders. It is said that when the engine has become heated it will be easily started without priming by one or two forward thrusts of the foot.

The step-starter used on the Harley-Davidson motorcycle is shown

in some detail at Fig. 268. The arrangement is such that a pair of pedals are provided just as in the usual construction, though no chain extends from the pedal crank hanger to the hub. Instead, the engine is rotated directly from the pedals through an ingenious ratchet and pawl arrangement. The pawl-carrier plate is securely attached to the pedal crankshaft, and when that member is rotated forward, the

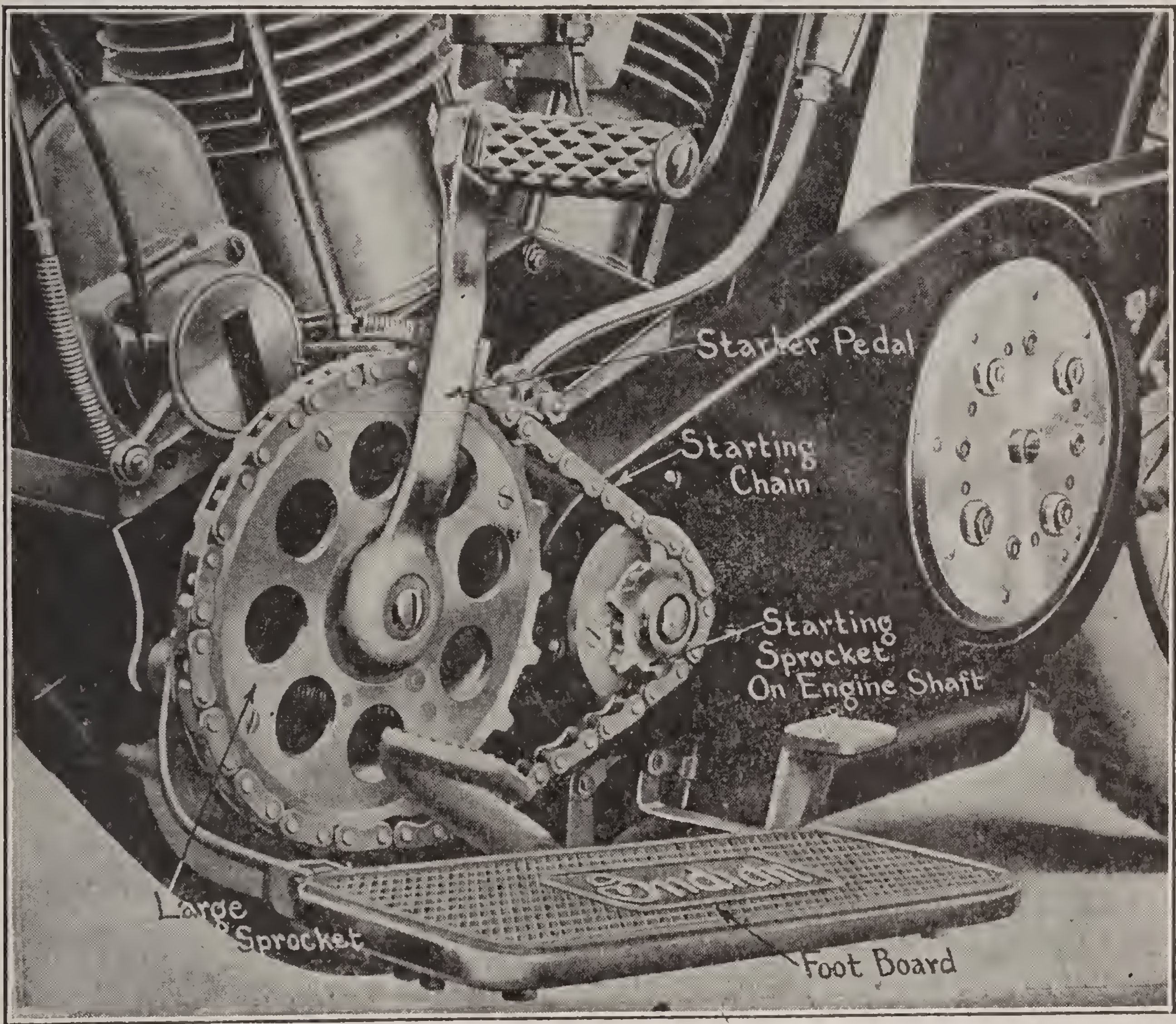


Fig. 267.—Outlining Construction of Indian Kick Starter Used on Two Speed Models.

pawls fly out and drop into suitable depressions in the ratchet ring which is attached to the first reduction sprocket, and which transmits the motion of the crank directly to the small sprocket on the engine shaft. The countershaft assembly includes a substantial ball-bearing carrying the member on which the first reduction sprocket and the rear wheel drive sprocket revolve. As soon as the engine is started,

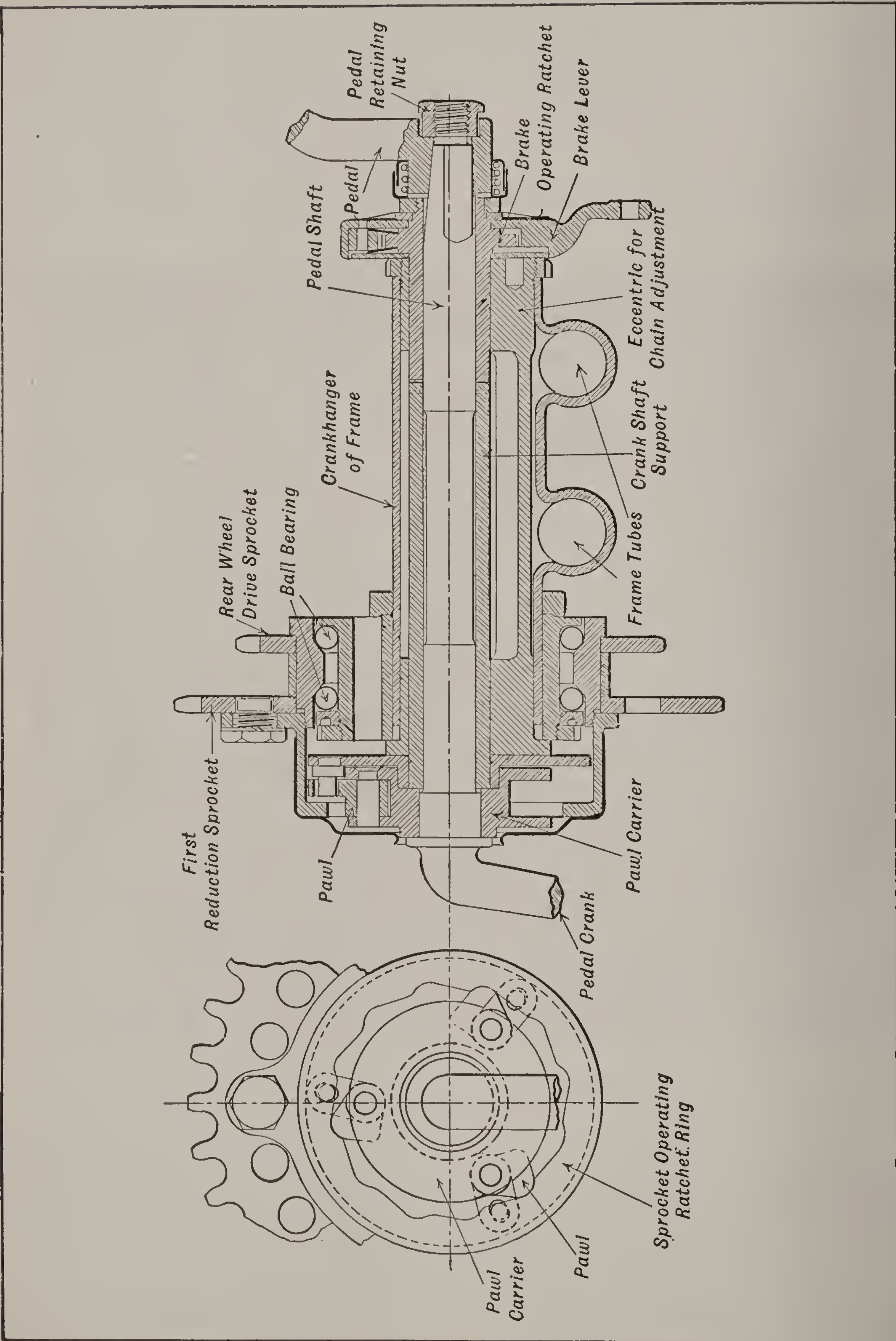


Fig. 268.—Sectional View Showing Construction of Harley-Davidson Kick Starter.

the pawls are released automatically and remain out of engagement as long as the ratchet revolves faster than the pawl-carrier plate. Another ingenious fitting is a ratchet which works only on back-pedaling carried at the other end of the countershaft which is used to operate the brake on the rear hub from the pedals when desired.

Electric Starting and Lighting Systems.—Electric lighting has long been recognized as an ideal illuminating system for motorcycles as well as motor cars, but it has been somewhat difficult to apply an electric lighting system successfully to rigid frame machines. The vibration encountered tended to rapid depreciation of the batteries, and if attempts were made to utilize current delivered directly from a small dynamo driven from the engine, other difficulties were encountered. Either the rider was experiencing continual trouble with the small round leather belts used in driving the generator or he was burning out a bulb, when the motor was suddenly accelerated and the generator produced an excess amount of current. If the motor was run slowly, the generator would not deliver enough current and the lights would burn dimly. In some models of the Indian motorcycle, two sets of batteries are furnished and are separately connected to the light. With reasonable precaution, the rider should never be without current for lights and electric horn operation. In the machines without the electric starter attachment when the lights become dim, the battery in service is cut out and the fresh battery carried in reserve is connected to the circuit. The batteries do not depreciate from vibration on account of being carried by the spring frame which insulates them from road shocks. A patented safety vent is used which permits the escape of gas from the battery interior, but which absolutely prevents the leakage of any of the electrolyte. Therefore, in passing over rough roads, or if a machine upsets in a fall, there is no weakening of the batteries by loss of liquid.

The Hendee special model, which is clearly the highest developed form of motorcycle ever offered, inasmuch as it not only incorporates full equipment including the various necessary accessories but also has a two-speed gear and electric self-starter, is shown at Fig. 269. On this model, the batteries are so connected that both of them discharge into the electric starting motor to secure the highest amperage for turning the engine over as fast as possible. It is said that it is

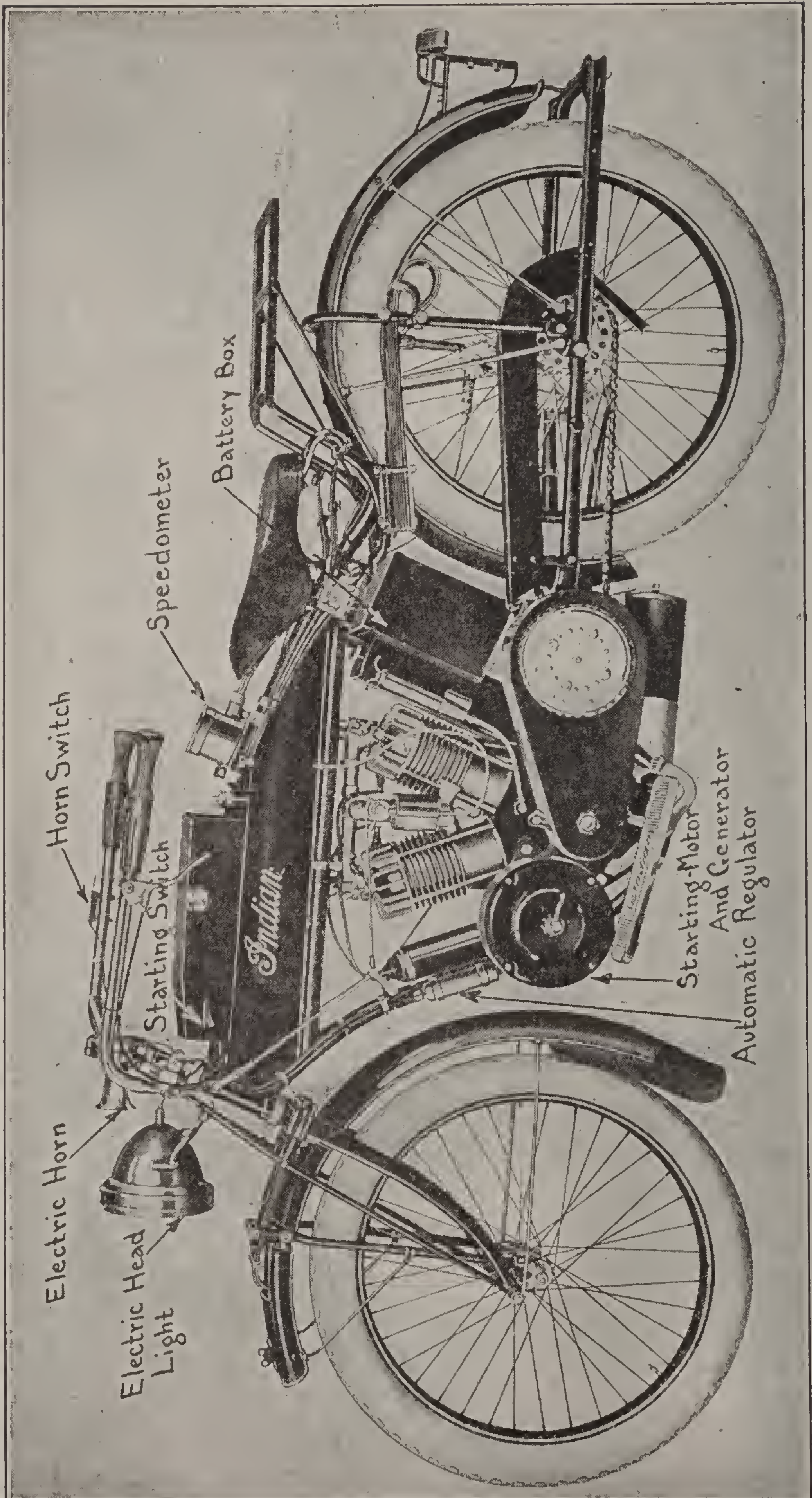


Fig. 269.—The Hendee Special Motorcycle With Electric Motor Starting Attachment.

possible to crank the engine over at the rate of 500 revolutions per minute, which is faster than any automobile starter. The nominal rating of the combined electric starter and generator is 1.5 horsepower, but the power actually developed is influenced by the energy necessary to start the engine. The starter has a high over-load capacity, and just as soon as the engine begins firing, the starter automatically becomes a generator and delivers a current that charges

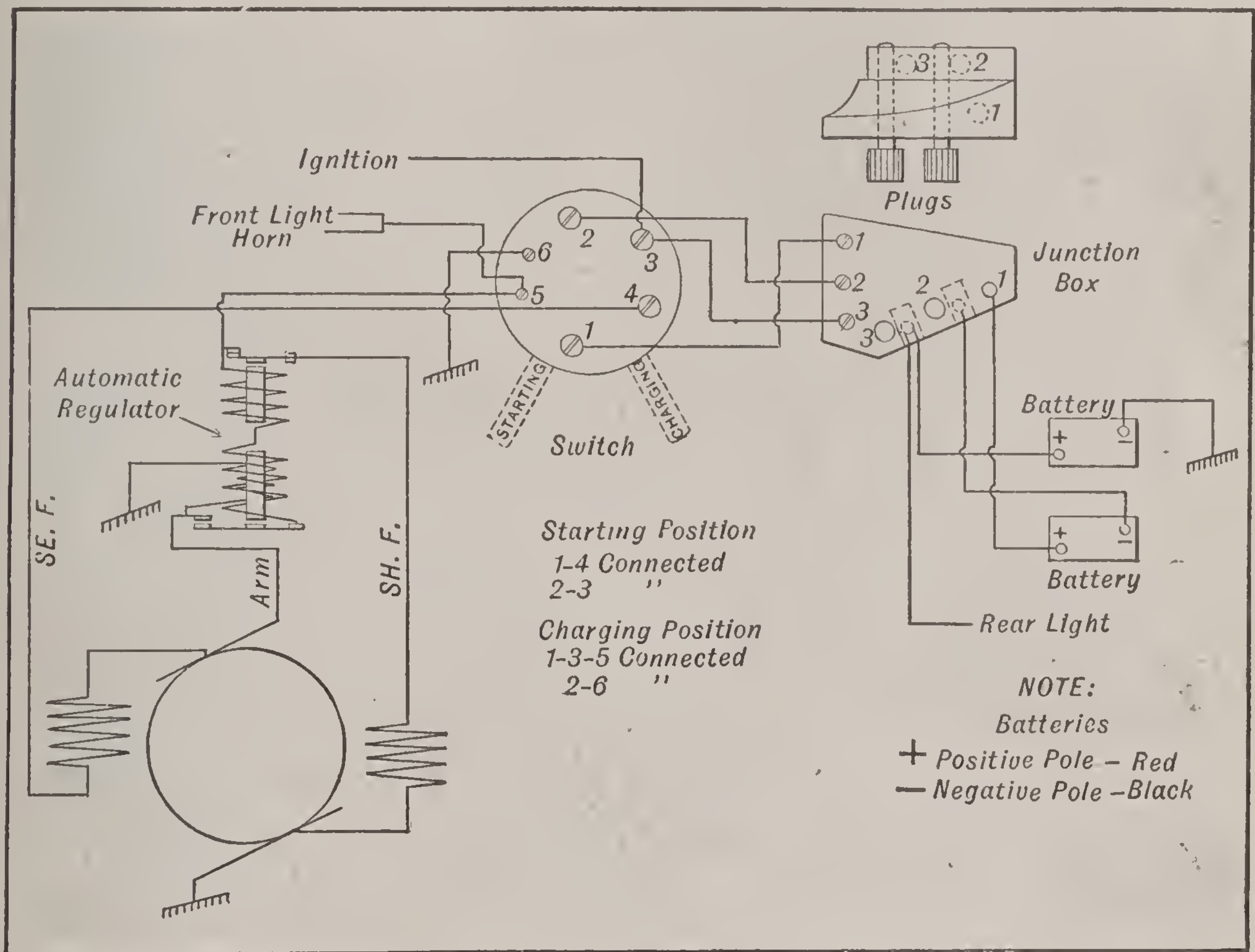


Fig. 270.—Wiring Diagram Showing Connections and Circuits for Electric Starting and Lighting System of Hendee Special Motorcycle.

the storage battery. The generator is always running while the engine is in operation, and an automatic regulator is included in the system so that when the batteries are fully charged the surplus electricity generated is dissipated. The current consumption of the lighting system is approximately two amperes. When the batteries are connected in multiple a current of 6 volts and 70 amperes is available, and when joined in series a current of 12 volts and 35 amperes is

available for starting. The batteries are charged at a road speed of 12 miles per hour on the high gear, and the maximum charging current flows to the batteries when the machine is operated at 16 miles per hour.

As shown at Fig. 271, the electric starter is attached to the engine crankshaft by a roller chain, and is geared approximately 2 to 1. It is said that under ordinary operating conditions, it will start a cold motor in 12 or 15 seconds. When a motor is warm but 3 to 5 seconds

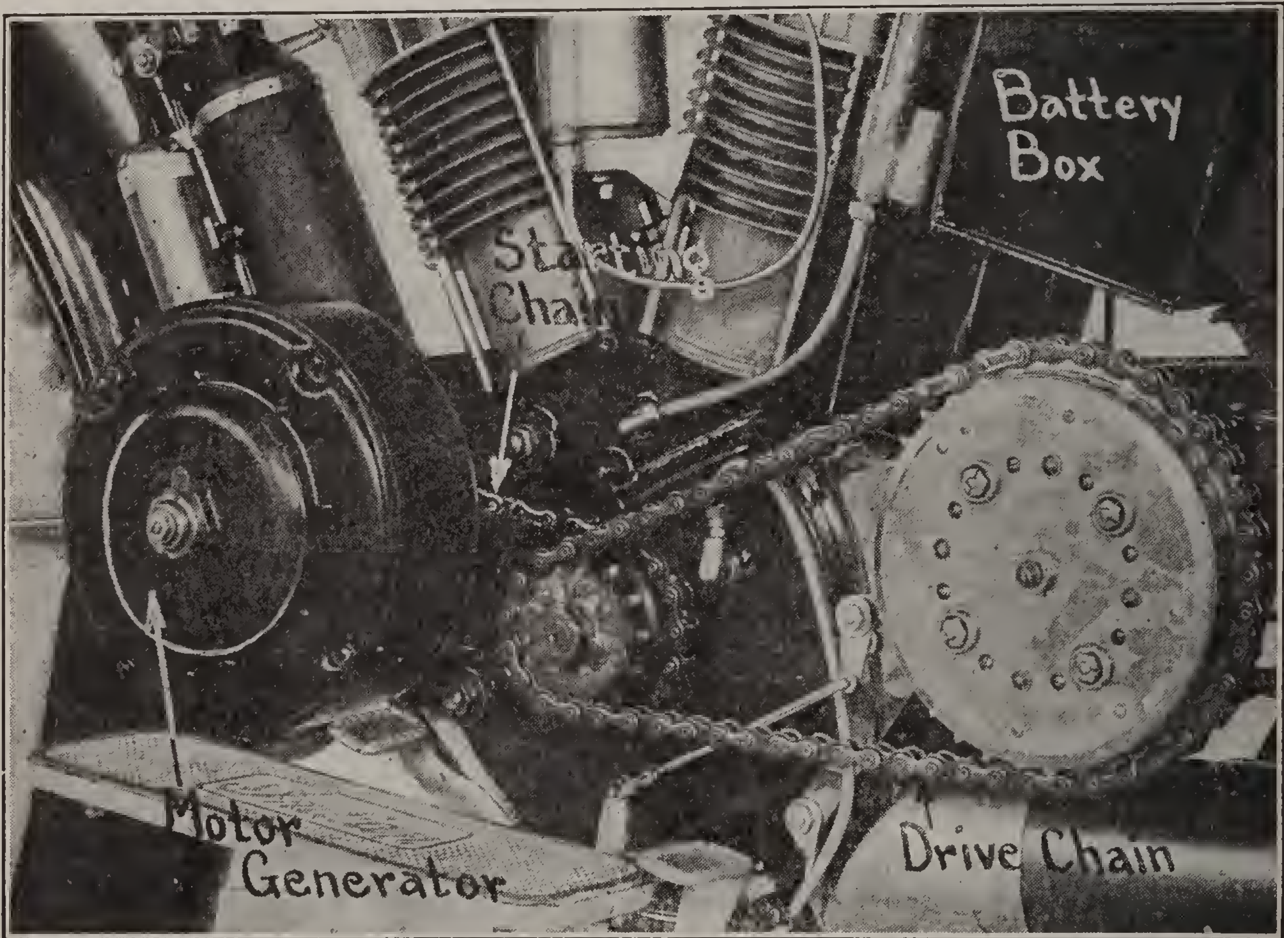


Fig. 271.—Showing Method of Driving Combined Motor-Generator of Hendee Special by Roller Chain From Engine Crankshaft.

will be necessary to start it. As the generator is constantly charging the batteries while the engine is running, the possibility of the cells becoming discharged is very slight. The current for ignition is derived from the batteries instead of from the usual high tension magneto, and as the batteries are kept fully charged, the main objection advanced against battery ignition, that of irregular and uncertain current supply, does not apply in this case. A wiring diagram showing the connections of the system is presented at Fig. 270.

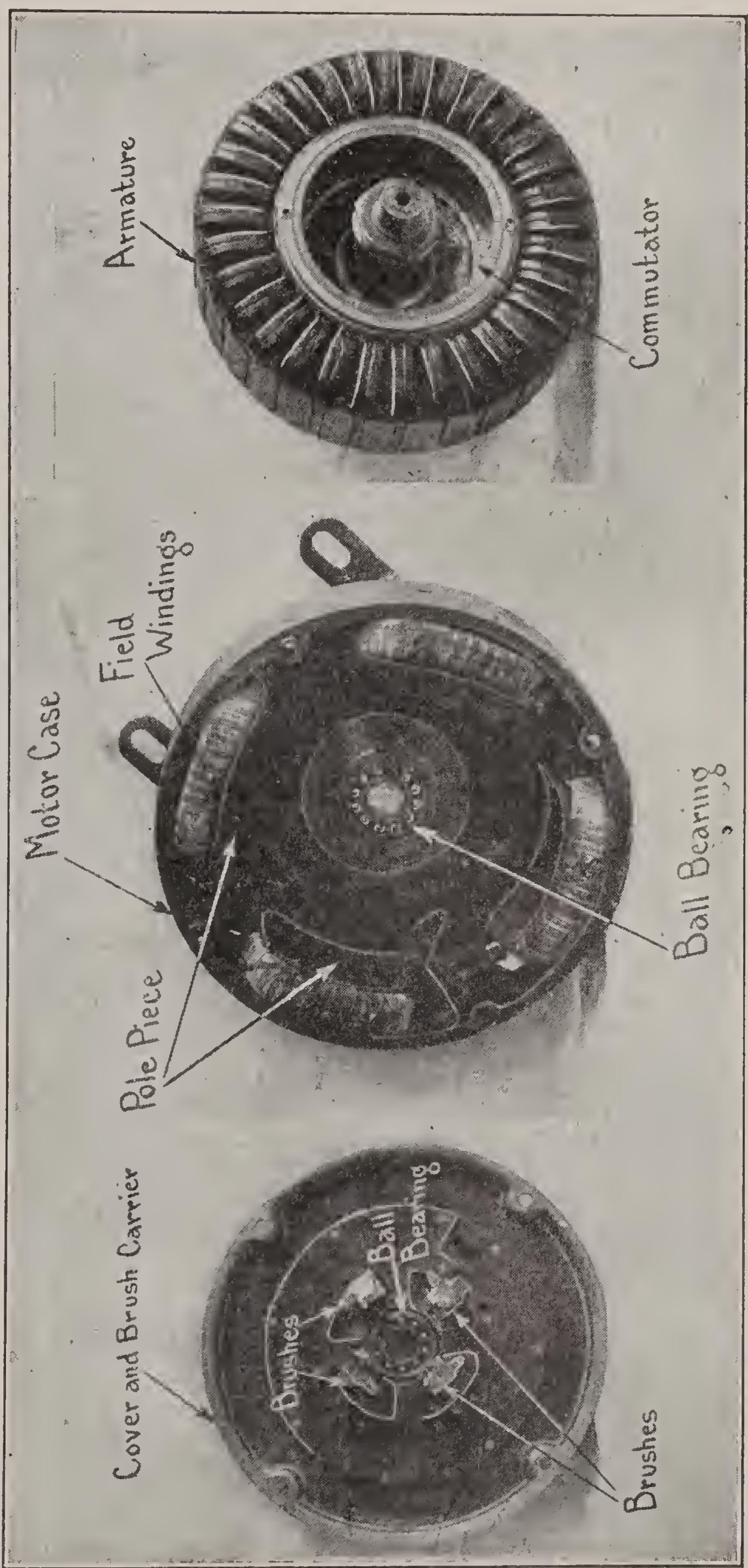


Fig. 272.—Parts of Combined Motor-Generator Used on Hendee Special Motorcycle.

The combination motor-generator used in connection with this system has been designed especially for the work, and as may be readily ascertained from the views at Fig. 272 it is a very compact and effective piece of electrical apparatus. In order to keep the device to the proper width, an internal commutator is used which is carried inside of the armature member. The brushes are supported by the cover plate, and project into the interior of the armature to make

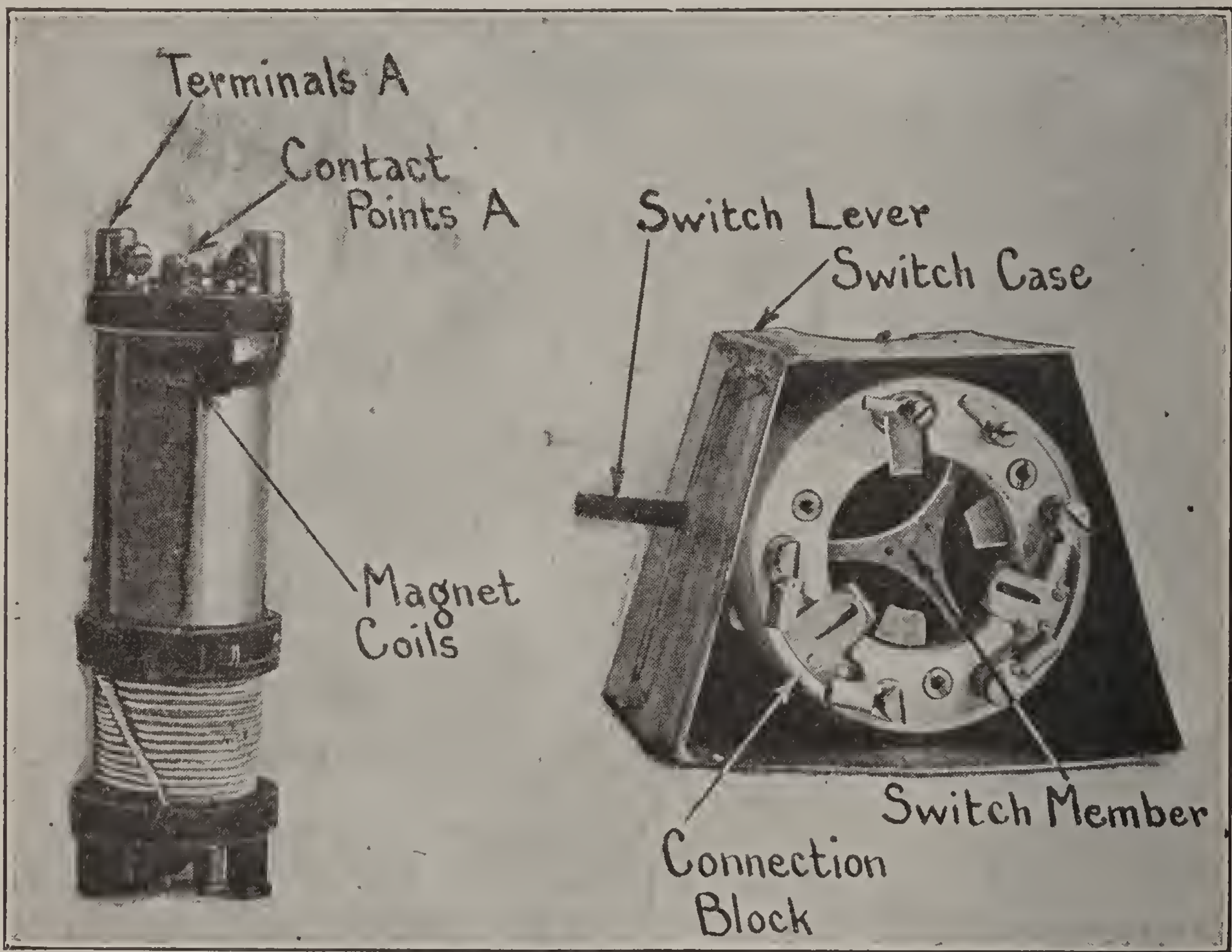


Fig. 273.—The Automatic Regulator and Control Switch Used in Connection With the Indian Electric Starting System.

suitable connections with the commutator segments placed therein. The armature shaft revolves on single row annular ball-bearings, and the device thus works with minimum friction. By a simple change of the wiring which is accomplished by a manually controlled switch at the front end of the tool box, the device may be converted into either a dynamo or a motor. The automatic regulator and switch member used in connection with the system are shown at Fig. 273.

When the switch is placed in the starting position, the circuits are arranged so that current is drawn from the batteries and directed to the starting motor fields. When the switch handle is moved back for the running position, the circuits are altered so that the current delivered from the generator armature is supplied to the batteries, first passing through the automatic regulator, which operates on a magnetic principle so that current is being supplied to the batteries only when it is of proper value for charging those members. As soon as the engine stops rotating, if the switch is left in the charging position, the automatic regulator will break contact and prevent the batteries discharging back through the windings of the motor-dynamo. The automatic regulator also functions and disconnects the windings from the batteries at such time that more than the charging current is delivered. The low current release portion of the automatic regulator also serves to break the circuit, when the power plant is running at rates of speed that would produce less than the proper amount of current for charging.

Motorcycle Control Methods.—When the motorcycle was first evolved, there was no attempt made to have the control arranged in a convenient manner, as the various levers by which the motor speed was varied were placed at any point on the frame that proved convenient for the designer in attaching regardless whether it was the best position for the person who would operate the machine. At the present time, every effort is made to locate the important and frequently manipulated control members where they can be easily reached, and very often the arrangement is such that the rider may have complete mastery of the machine without removing the hand from the handle bars. The control of American motorcycles is considerably simpler than that generally provided on the foreign mounts, as the common practice in this country is to regulate the motor speed through the medium of twisting grips. Of course, when a two-speed gear is used, an auxiliary control member is placed convenient to the rider to regulate the gear ratio desired, and on some machines still another lever is used to control the free engine clutch. Several of the American motorcycles employ grip control of the free engine clutch, prominent among which may be mentioned the Schickel, Excelsior and Eagle machines. For use in traffic, or operating under conditions

that necessitate frequent use of the clutch, it is apparent that the most convenient method is by the grip because this does not require the rider to take his hands from the handle bars which insures positive control at a time that it is most needed. The free engine clutch is regulated on some machines through the medium of a pedal, and this control is very satisfactory on machines equipped with running boards to support the rider's feet and where the usual form of pedaling gear is dispensed with.

The first of the American manufacturers to utilize grip control, to

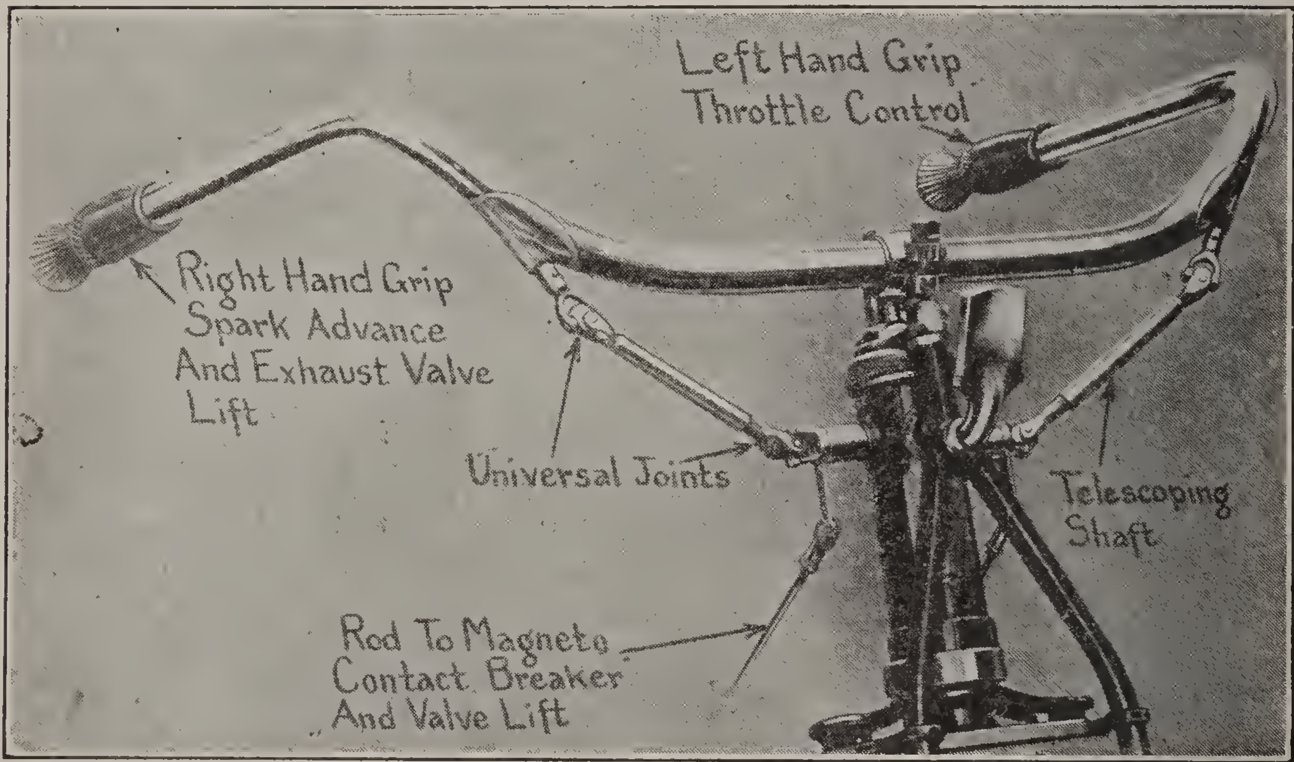


Fig. 274.—Handlebars of Indian Motorcycle, Showing Method of Motor Control by Twisting Grips.

regulate engine speed, were the makers of the Indian motorcycle, and this method was incorporated in even the earliest models of these machines. The method of regulating the motor speed and the construction of the universal joints and rods used in connection with practically all Indian models is shown at Fig. 274. The right hand grip controls the spark advance and the exhaust valve lift. The valves are lifted to relieve the compression and to make it possible to turn the engine over easily for starting. The left hand grip is used to control the throttle. The twisting movement of the grips is transmitted by means of a flexible shaft running from the grip through the

hollow tube comprising the handle bar to a bearing from which the end of the shaft projects. A universal joint attached to this shaft transmits its motion to a compound member consisting of one shaft telescoping into another, that is secured to the actuating lever attached to the steering head. The reason for using the telescope shaft arrangement is that it is necessary to have some flexible connection other than the universal joint to permit the handle bars to be turned when steering the machine.

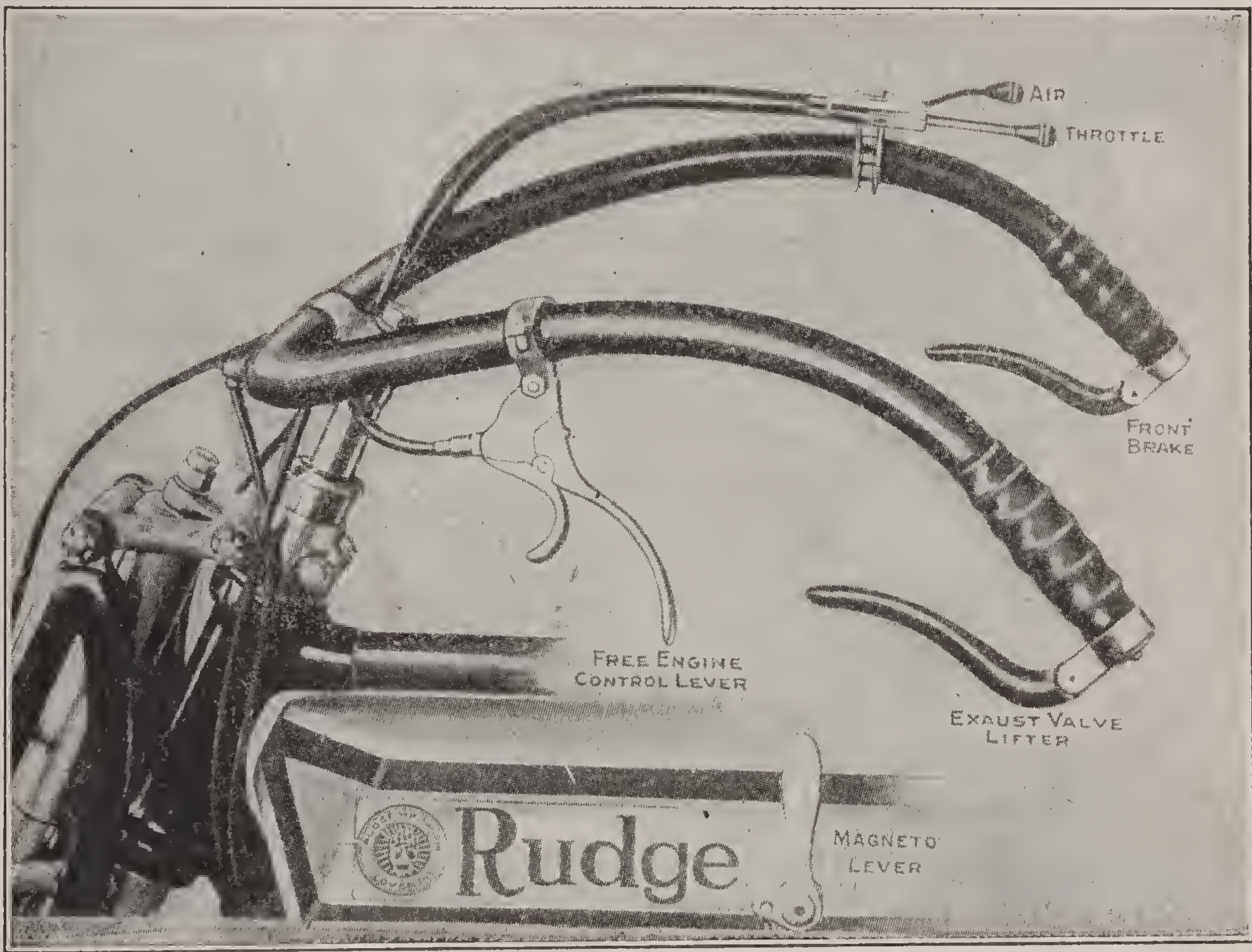


Fig. 275.—Control System of the Rudge Motorcycle, Typical of Foreign Practice.

If one compares this simple and direct control with that shown at Fig. 275, which is an illustration of a representative English construction, it will be apparent that the American design is considerably neater. Of course, on the single-speed Indian models it is necessary to have a lever to actuate the free engine clutch which is carried at the side of the machine and an auxiliary pedal is provided near the footboard to operate the hub brake. On the two-speed machines, a

lever is provided to shift the positive change speed clutch and a foot-controlled member supplied to release the master or free engine clutch. In addition to the control members shown at Fig. 275, there is another lever which is not illustrated, provided to operate the variable speed pulley. The control of the ignition is by a small lever at the side of the tank connected with the magneto contact breaker.

The speed of the motor is controlled by the magneto lever and by the air and throttle levers mounted on the handle bars and connected to the carburetor through the medium of Bowden wire control. At the end of each grip, a lever is fulcrumed, one being used to work the front wheel brake, which is a fitting prescribed by law abroad, while the other is the exhaust valve lifter. On the same bar that carries the exhaust valve lifter, a hand lever to control the free engine clutch is mounted and as is true of the other elements it is joined to the clutch member by the flexible wire connection. From the handle bar assembly shown, five of the Bowden wires extend to the various elements they are intended to control. One goes to the air slide of the carburetor, another to the throttle regulating the supply of gas. The third member goes to the exhaust valve-lifting arrangement, while the fourth and fifth extend to the free engine clutch and the front wheel brake respectively.

Bowden Wire Control.—While the Bowden wire control is used on practically all of the foreign motorcycles, and is employed to some extent on American machines as well, there is a general lack of understanding of its principle of action on the part of the American rider, and considerable trouble is experienced from time to time in fitting up or making repairs to this system. The Bowden wire mechanism consists mainly of two parts, one which, termed "the outer member," is a closely coiled and practically incompressible spiral spring while the "inner member" is an inextensible wire cable passing through the outer member which acts as a casing. The usual mechanical method of transmitting power in other than a straight line in this country is by means of universal joints, small bell crank levers and suitable connecting rods. The Bowden wire mechanism is considerably simpler and is easily fitted. The principal requirement is that the outer member or casing shall be anchored to a stop at each end, while the

inner member is attached to an operating lever at one end and to the object to be moved at the other.

A diagram showing the method of operation is shown at Fig. 276, and the reader should have no difficulty in understanding the action of this control system. A line of Bowden wire mechanism sufficient to reach from the point where the object is to be moved to the point where the necessary power is to be applied is represented by D D D. The outer cable of the mechanism is passed around any intervening corners or obstacles. At C C the inner member of the mechanism will be seen emerging from the outer case being attached at one end

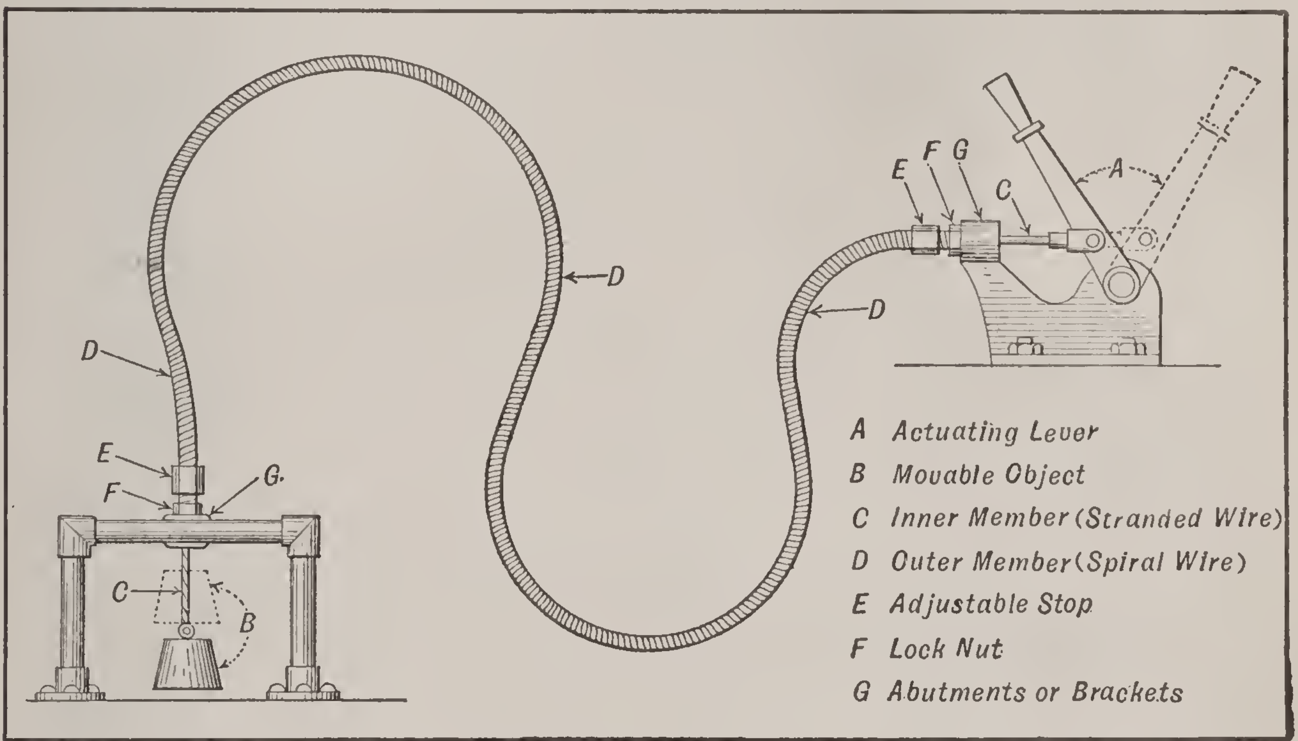


Fig. 276.—Diagram Explaining Action of Bowden Wire Mechanism.

of the actuating lever A and at the other to the object to be moved B. The outer member is anchored to fixed abutments G G. If the lever A is moved, the motion is at once imparted to the other end. When being actuated, the mechanism will exhibit a wriggling movement at the curves because the inner member attempts to reach the straight line of pull, but is resisted by the outer casing which cannot shorten its length inasmuch as it is anchored at both ends. The movement should not be restrained, as the mechanism functions best when the curves are free. The dotted lines show the lever A in its actuated position, and the weight B, or object to be moved, correspondingly

raised. E E are adjustable screws or stops, the screwing out of which is equivalent to lengthening the outer member, and are held in position by the lock nuts F F.

Various examples of the levers used in connection with Bowden wire mechanism are shown at Fig. 277. The hand lever with ratchet retaining lever shown at A is widely used for clutch actuation, brake application and lifting the exhaust valves. The assembly shown at B consists of two levers carried above the clamp, and a lifting lever below it. One of the upper members may be used to control the spark

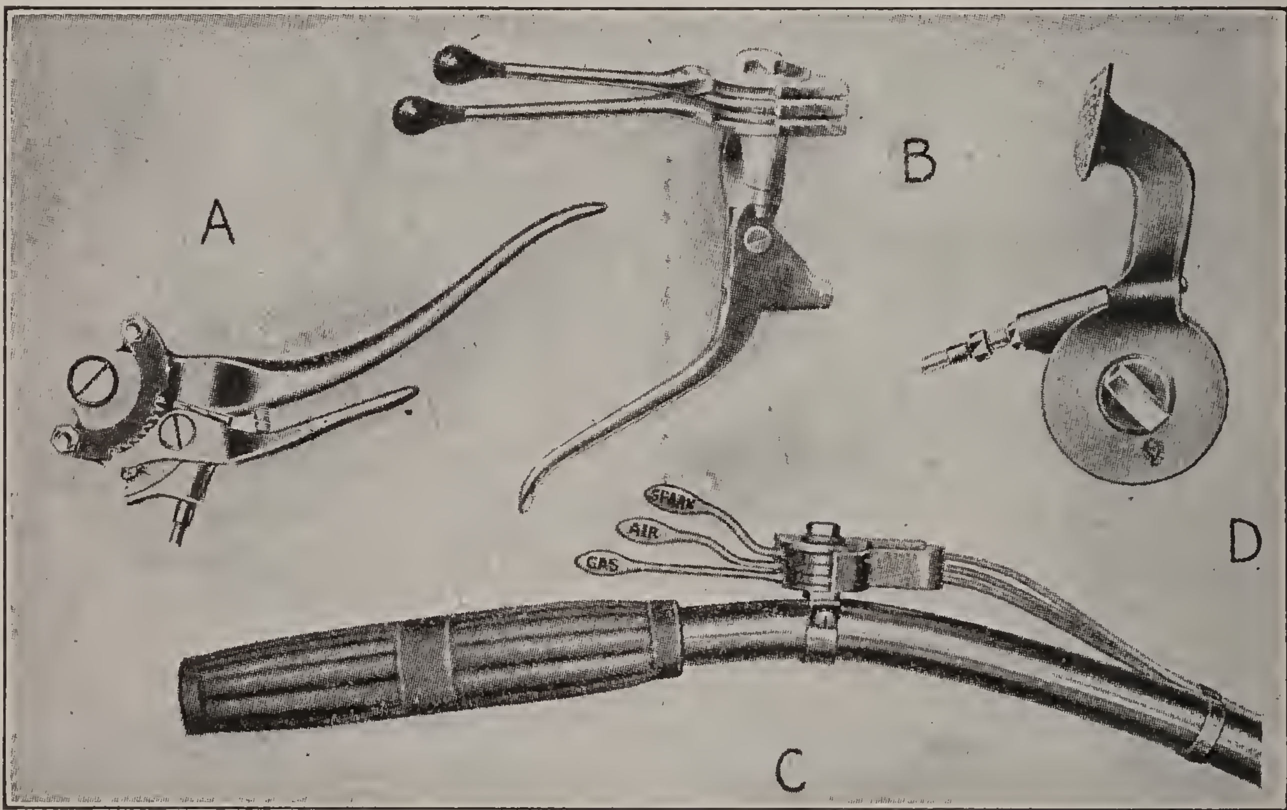


Fig. 277.—Showing Various Forms of Levers Used in Connection With Bowden Wire Mechanism.

time and the other connected to the throttle, or both may be used to regulate the carburetor. The handle at the lower part of the assembly may be connected to brake, clutch, or exhaust valve release. A group of three control levers, each being plainly marked to show the functions performed, designed for handle bar attachment is shown at C. The pedal at D is adapted for brake actuation.

The Bowden wire control is also sold in connection with complete control devices, two popular fittings being outlined at Fig. 278. At A a front wheel brake assembly is shown. The contact blocks which

bear against the wheel rim are carried by a U-shaped member that is held at its lower portion by clips attached to the fork sides. The upper portion may be guided by any suitable bracket and is connected with a hand lever intended to be attached to the handle bar by a length of the Bowden wire mechanism. An auxiliary air fitting and suitable controlling means are shown at B, while the usual method of rigging up to a magneto contact breaker is shown at C.

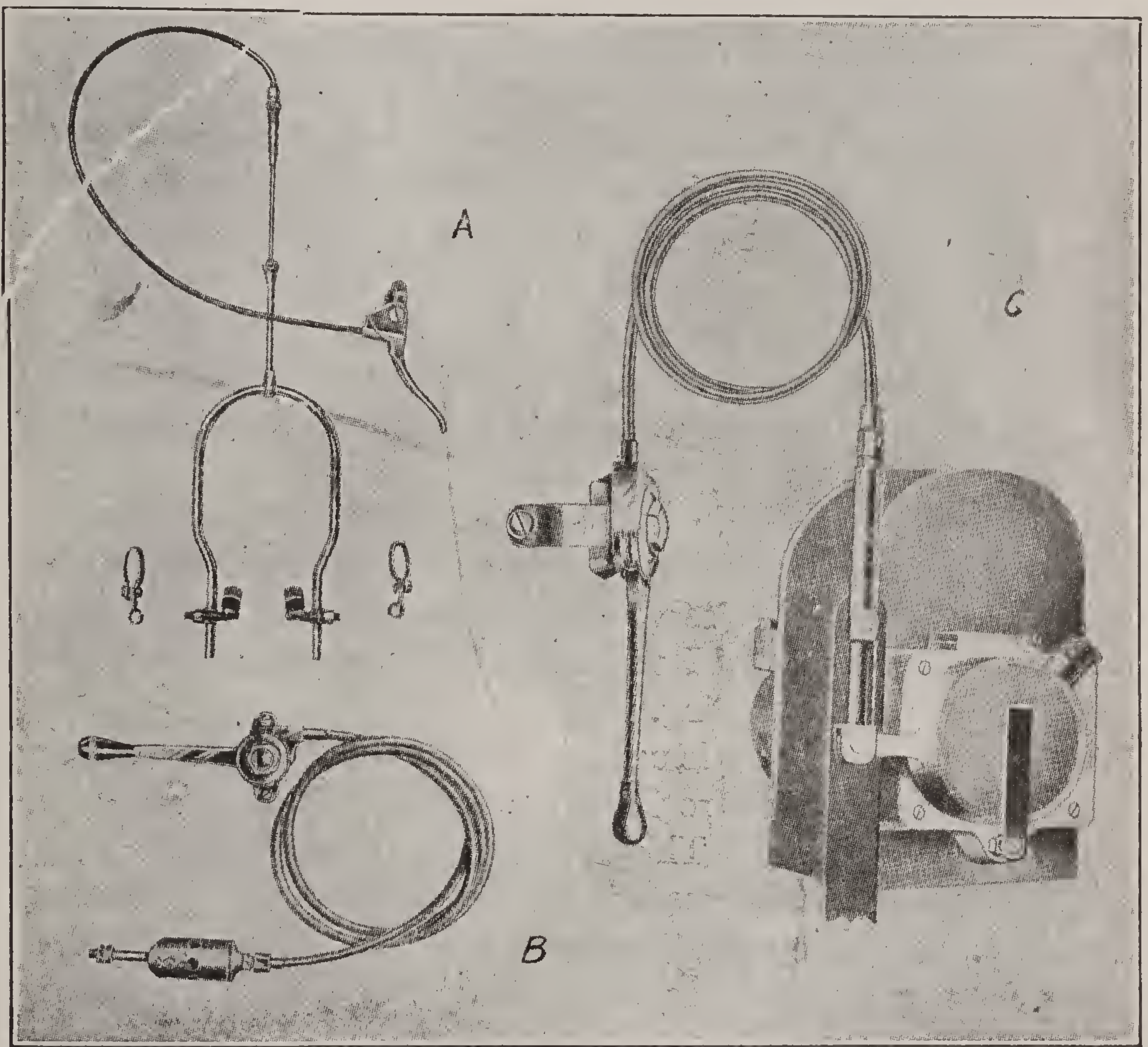


Fig. 278.—Showing Practical Application of Bowden Wire Mechanism for Controlling Front Wheel Brake, Auxiliary Air Intake and Magneto.

The following hints on fitting the Bowden wire mechanism, given by the makers, will undoubtedly be found of value by riders and repair men who are not thoroughly familiar with the application or maintenance of this system of control.

It is important that the inner member of the mechanism should be soldered before it is cut, as it is composed of a number of fine strands which are liable to become untwisted unless this precaution is taken. With the smaller sizes, up to No. 3, a pair of pliers or a spoke-cutting machine will suffice for cutting, but larger sizes will require a file or cold chisel to sever the strands.

The brass nipple supplied for the purpose should be carefully attached to the end of the inner member. A good method of effecting this is as follows: The wire, after being soldered and cut, should be passed through the nipple, the end then being nipped flat for about 1/16 inch. This will prevent it drawing out again during the process of soldering the wire and nipple together, which should be done in combination with a non-corrosive soldering fluid (on no account should killed spirit be used), care being taken that the soldered joint extends the full length of the nipple. The nipple should then be held in the vise, and the wire burred over and finished off with a blob of solder. It will then be found impossible to remove the nipple by any fair means.

For the varieties of the mechanism known as Bowdensilver, Bowdenbrass, and Bowdenite, special metal caps are provided for encasing the ends. These serve the purpose of finishing the ends off neatly, and, in the case of Bowdensilver and Bowdenbrass, prevent the protecting cover uncoiling.

When a single-pull lever is used, it is necessary to have a spring at the opposite end of the wire to which the lever is fixed, in order to ensure prompt recovery. This spring may be made either to pull the inner member back through the outer member, after pressure has been relieved from the operating lever, or it may be inserted between the stop holding the outer member and the end of the inner member, in which case, of course, it will be in compression. In the latter case, it will generally be found that the simplest method of fixing is to fit the device up minus the spring, and to wind the spring on afterward, as one puts a key on a split ring. But when a double-pull lever is used, a spring is not necessary, as the separate mechanisms so balance each other that while the lever is pulling on in one direction it is pulling off in the other.

Care should be taken that the inner member, on leaving the stop

in which the outer member terminates, should be kept in an absolutely straight line, as should it be otherwise, it will rub on the edge of the stop, and be gradually worn away in consequence.

The inner member should be thoroughly smeared with motor grease or vaseline before being passed through the outer member.

CHAPTER VII.

CONSTRUCTIONAL FEATURES OF CYCLECARS.

Advantages of Cyclecars—Influence of Motorcycle Design—Three Wheel or Tri-car Forms—Typical True Cyclecars—Seating Arrangements—Advantages of Narrow Tread—Cyclecar Chassis Design—Cyclecar Power Plants—Cyclecar Change Speed Gears—Power Transmission Methods—Steering Arrangements—Methods of Springing—Cyclecar Control Methods.

Considerable interest obtains at the present time in a new form of motor vehicle, known as the "cyclecar." These small vehicles are of two general types, both of which will, undoubtedly, receive wide application. Some of the vehicles that are termed "cyclecars" are in reality miniature automobiles, and do not conform to the precise definition generally accepted for cyclecars. While engineers and designers disagree upon the characteristics of the new vehicle, it is generally believed that the term "cyclecar" should be applied to light four-wheeled vehicles using motorcycle parts in their construction.

The true cyclecar offers a number of features that will enable it to fill a distinct field that cannot be catered to by the builders of either low-priced automobiles or motorcycles. In the cyclecar there is a lack of complication in the mechanism, a low center of gravity making for stability is obtained, a streamline body construction, especially in the tandem seating arrangement, is possible which reduces wind resistance to a minimum. While at the present time there are no reliable statistics regarding the cost of maintenance in this country, if one reasons from experience with a motorcycle and sidecar combination, it is possible to arrive at the conclusion that two persons can travel over average highways at a total cost for fuel and tires of not more than two cents per mile, whereas it would cost at least three times this sum to cover the same distance with the lightest form of miniature motor-car. Several designs are being produced at the present time in this

country that will sell at prices ranging from \$350 to \$450, and it would seem reasonable to assume that many people could afford to purchase a cyclecar who would not be interested in a small automobile on account of its higher initial cost and greater maintenance expense, and yet who would not favor the motorcycle or sidecar combination at the same cost, on account of the greater protection and easier control of the cyclecar.

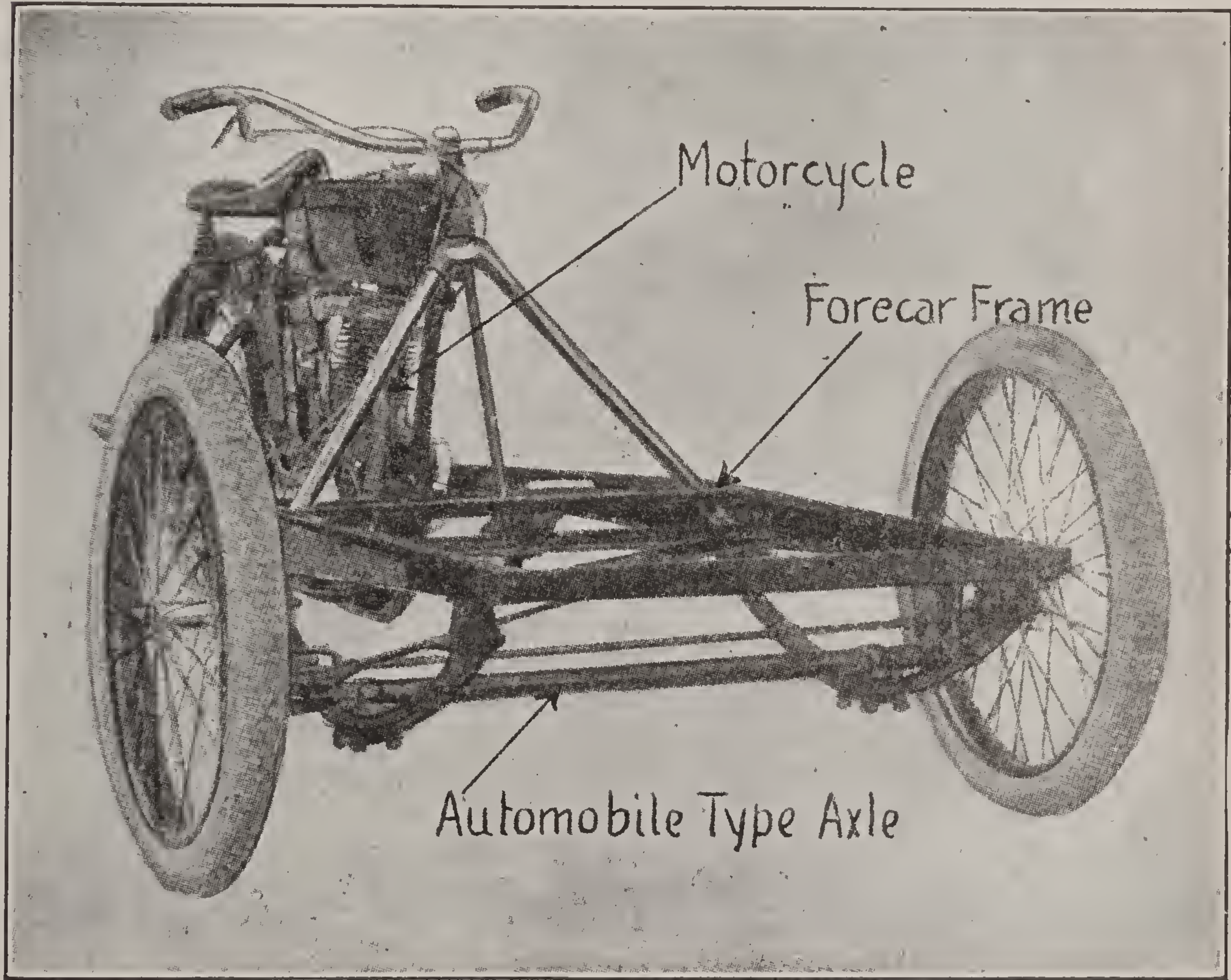


Fig. 279.—Chassis of Motorcycle With Forecar Attachment, the Original Form of Cyclecar.

The greatest advantage of the cyclecar must always be its wonderful economy. The simpler forms do not weigh any more than a combination of a motorcycle and sidecar, and the true cyclecars should cost but little more to operate than a motorcycle. One of the chief items of expense in even the smallest of the automobiles is tires, and it is evident that where engines of comparatively low power are used there will be no necessity for the sizes of tires designed to support

heavier and more powerful vehicles of the light car pattern. The small size of the power plant also insures that minimum gasoline and oil will be consumed. The cyclecar may be easily handled, as for the most part the control is by regular automobile methods, and at the same time the small size enables one to use a small shed instead of the special garage necessary with the larger car. The cyclecar has attained a great popularity in this country as well as abroad, and whereas there were not more than eight or ten types of cyclecars

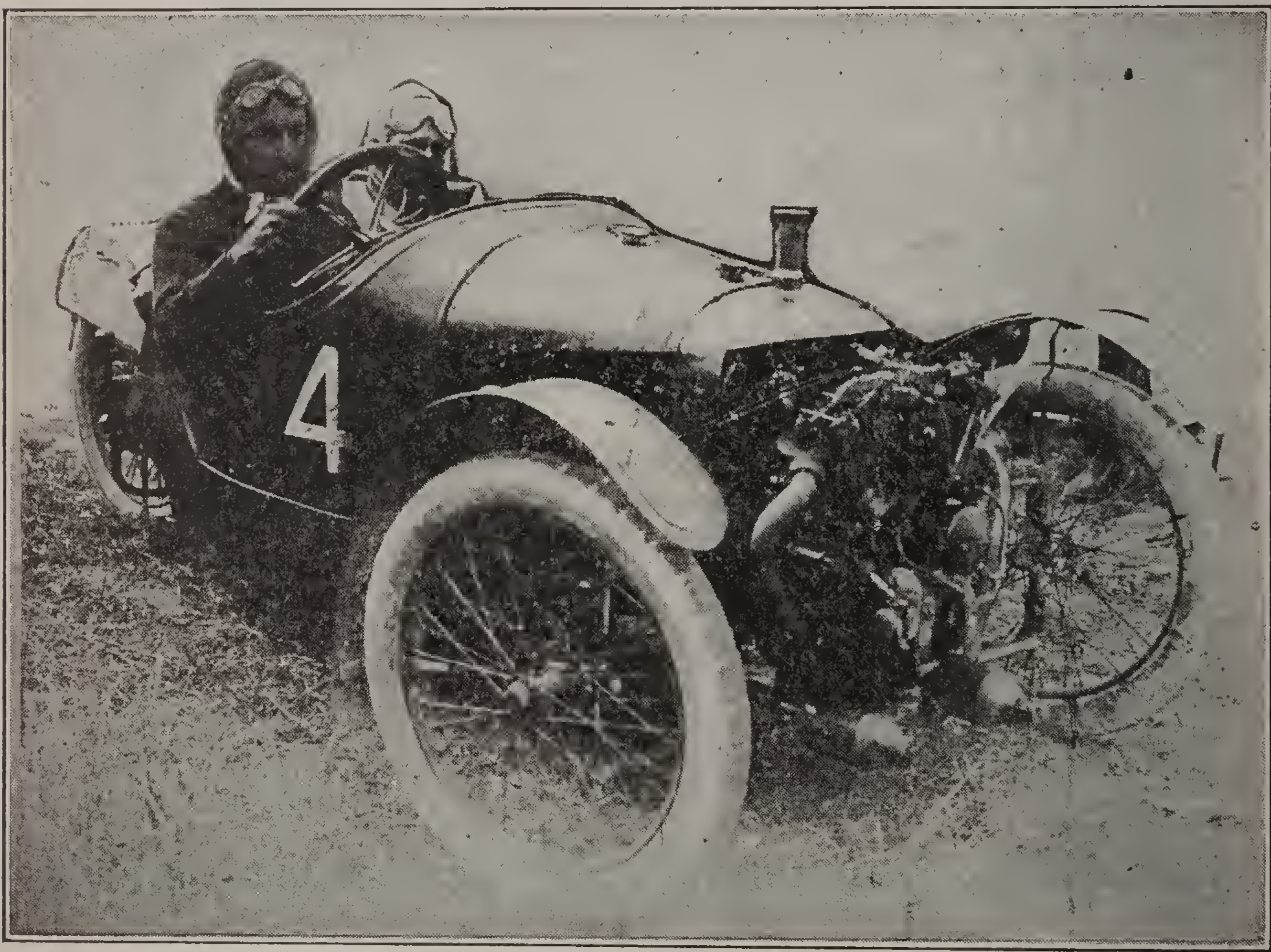


Fig. 280.—The Morgan, One of the Best Known of English Three Wheelers in Racing Trim.

available a year ago, and these all of foreign manufacture, there are, at the present time, over three hundred makers of cyclecars in the United States, England and France.

The cyclecar appeals to the owner of an automobile as an auxiliary, as its simple and light construction and economy enables the motorist to use this in running around as in doing errands, making short local and suburban trips and, in fact, using it at all times that it would not

be worth while to start and operate the larger car. The motorcyclist will be interested in the cyclecar, because, for the most part, these vehicles incorporate features with which he is already familiar. The four-wheel form is an excellent means of taking two passengers about with more comfort, for the driver, than would be obtained with either motorcycle and tandem attachment or a motorcycle-sidecar combination. Apart from those who are already interested in either automobiling or motorcycling, there are thousands of conservative people, especially middle aged artisans or professional men of all classes, who

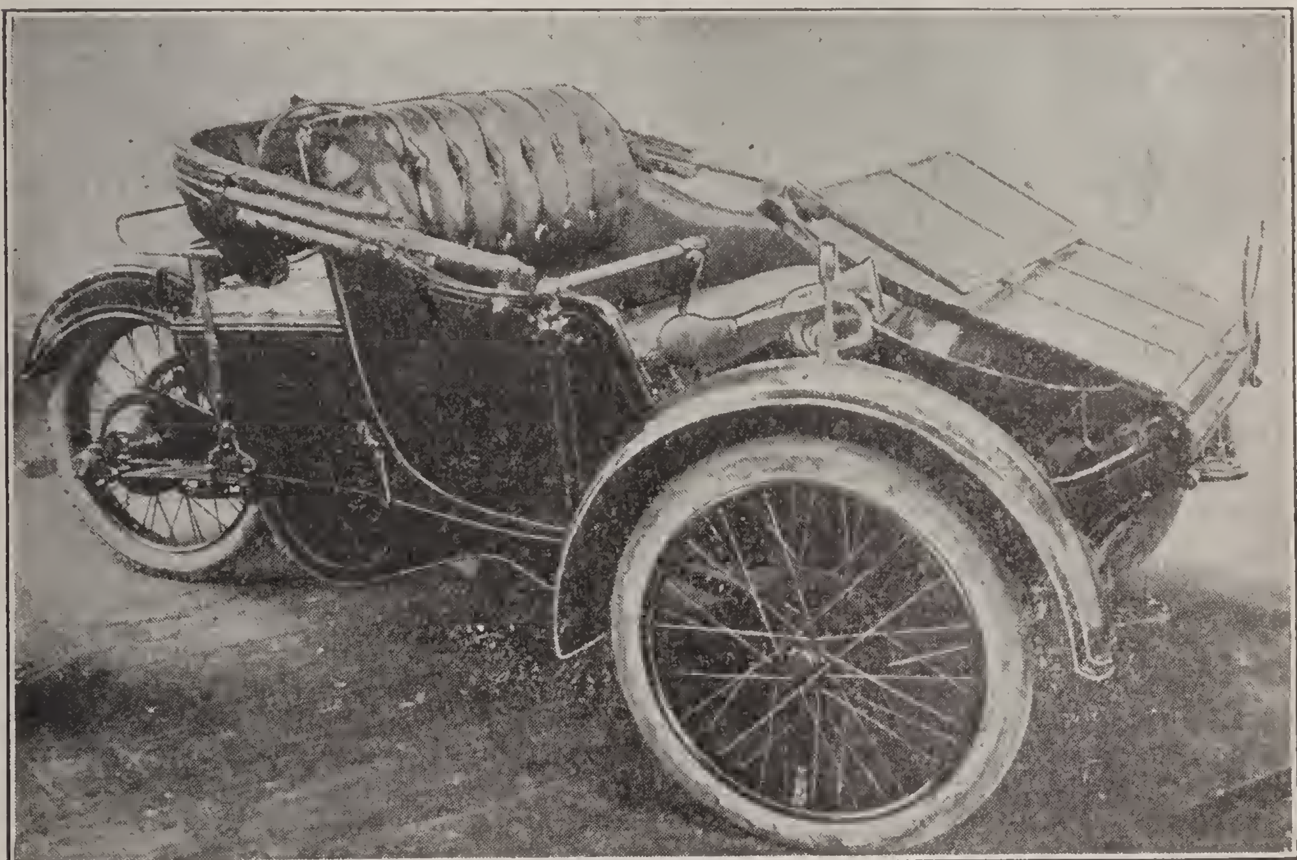


Fig. 281.—The Auto-Carrier's Two Passenger Three Wheeled Cyclecar Model.

do not take kindly to the motorcycle, and yet who cannot afford the upkeep of even the cheapest of American runabouts built on conventional automobile lines. The economy, simplicity, ease of handling and storage and other advantages of the cyclecar will appeal to these as a motorcycle or an automobile never could.

The definition of the cyclecar was decided on the 14th of December, 1912, at a meeting of the International Federation of Motorcycle Clubs, and the classification given at this meeting is said to hold good

in England, Canada, the United States, France, Holland, Belgium, Italy, Austria and Germany. Cyclecars are divided into two classes, a large and a small. The maximum weight permissible in the large class is 784 pounds, the maximum engine capacity to be 1,100 cubic centimeters (66+ cubic inches) and the minimum tire size 60 millimeters (approximately 2.25 inches). In the small class, the minimum weight shall be 330 pounds, the maximum 660 pounds. The maximum engine capacity is to be 750 cubic centimeters (45+ cubic inches) and the minimum tire size 55 millimeters. All machines are to have a clutch and change-speed gearing, and even those forms in which a clutch action is obtained by slipping the belts and changes of speed by varying pulley diameter are considered as complying with this regulation. This definition is by no means permanent.

Influence of Motorcycle Design.—Before the side-car forms of passenger carrying motorcycles were evolved, a two-wheel fore carriage replaced the usual front fork assembly, the whole forming a three-wheel conveyance that was very speedy and practical. The tricar is considerably easier to handle than the average sidecar combination, as the two front wheels were carried by an automobile type axle, and were controlled by the regulation Ackerman steering gear, universally applied on automobiles. The chassis of a typical three wheeler, of which a motorcycle serves as a basis, designed for commercial work, with the body removed to show arrangement of parts is clearly outlined at Fig. 279. There is no reason why standard motorcycle components could not be incorporated as a four-wheel vehicle, and the true cyclecar may be considered a four-wheel motorcycle, inasmuch as in practically all of the successful types, a regular two-cylinder air-cooled power plant of the V-type is used which drives through leather V-belt to wheels but slightly heavier than those used on the powerful motorcycle. Designers of cyclecars have profited considerably from the experience of motorcycle designers because in that vehicle it is necessary to obtain maximum strength, reliability and endurance by very careful selection of materials and proportioning of parts that were strong and yet not bulky. It is not strange, therefore, that in seeking to evolve vehicles capable of being sold at a low price cyclecar designers should avail themselves of the knowledge gained in building motorcycles and use some of the principles that

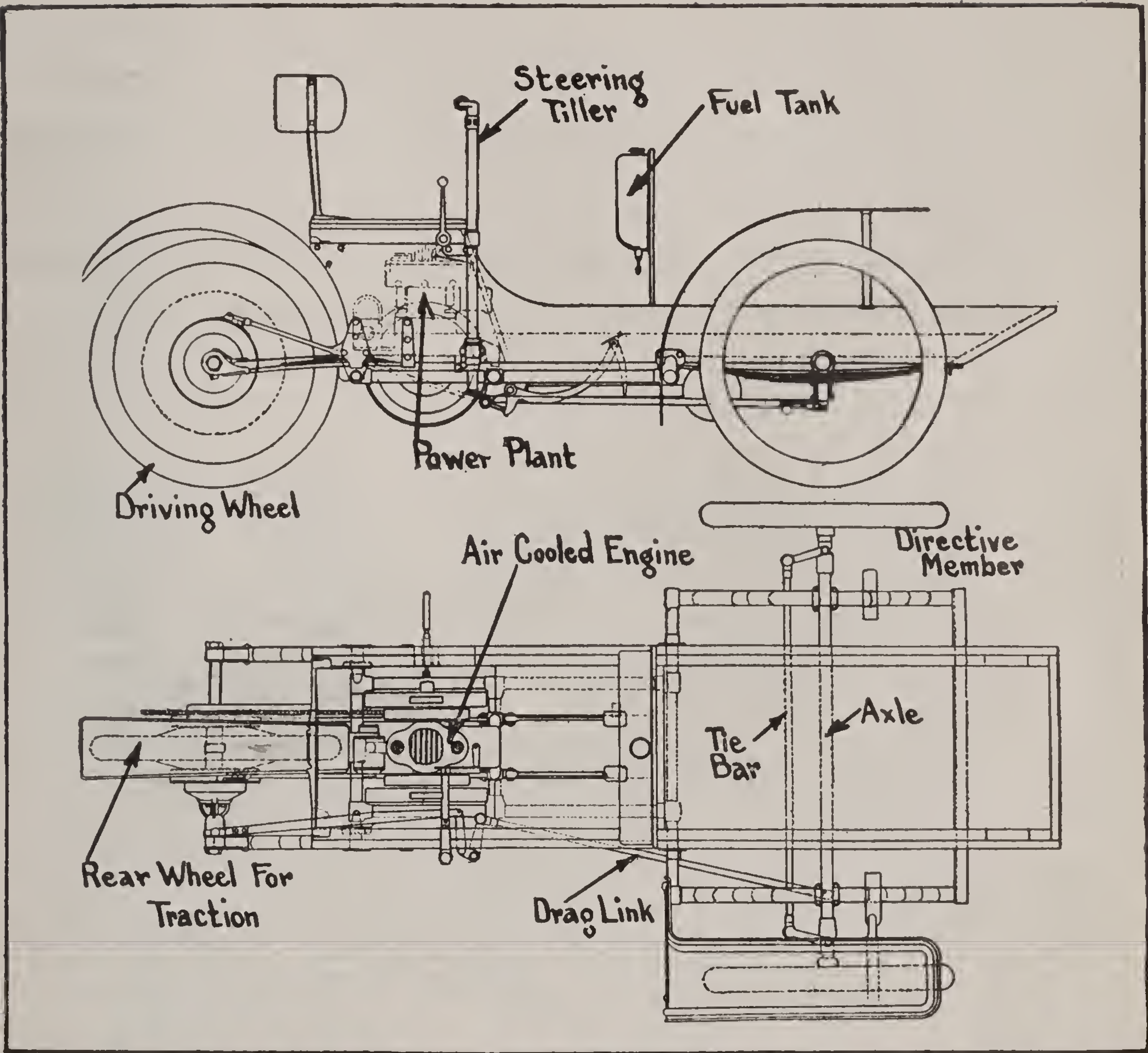


Fig. 282.—Side Elevation and Plan Views of the Auto-Carriers' Three Wheeled Chassis, Showing Unconventional Disposition of the Power Plant.

have been tried out on the two-wheeled vehicles and proven successful.

Those who are opposed to the cyclecar, call it a "hybrid" construction in which both automobile and motorcycle practice has been combined. This is true, as in most forms of cyclecars one will find features of both classes of vehicles. This is not anything to discredit the cyclecar, however, as the first automobiles were hybrids in which endeavor was made to propel horse-drawn vehicles by self-contained power, and, in fact, it is not unjust to say that the motorcycle of to-day is just as much of a hybrid as the cyclecar, because it includes many features of the bicycle with just as many taken from automobile

practice. The influence of motorcycle design on cyclecar construction has been a favorable one, inasmuch as it permitted the designer to evolve a new type of vehicle that, while light and simple, has ample power and sufficient strength to be enduring.

Three-Wheel or Tricar Forms.—The tricar construction or the three-wheeler has not been abandoned by any means abroad as is the case in this country. Many efficient and presumably satisfactory three-wheelers are in use in Europe. The reason given for the abandonment of the three-wheel construction, in pleasure vehicles, in this

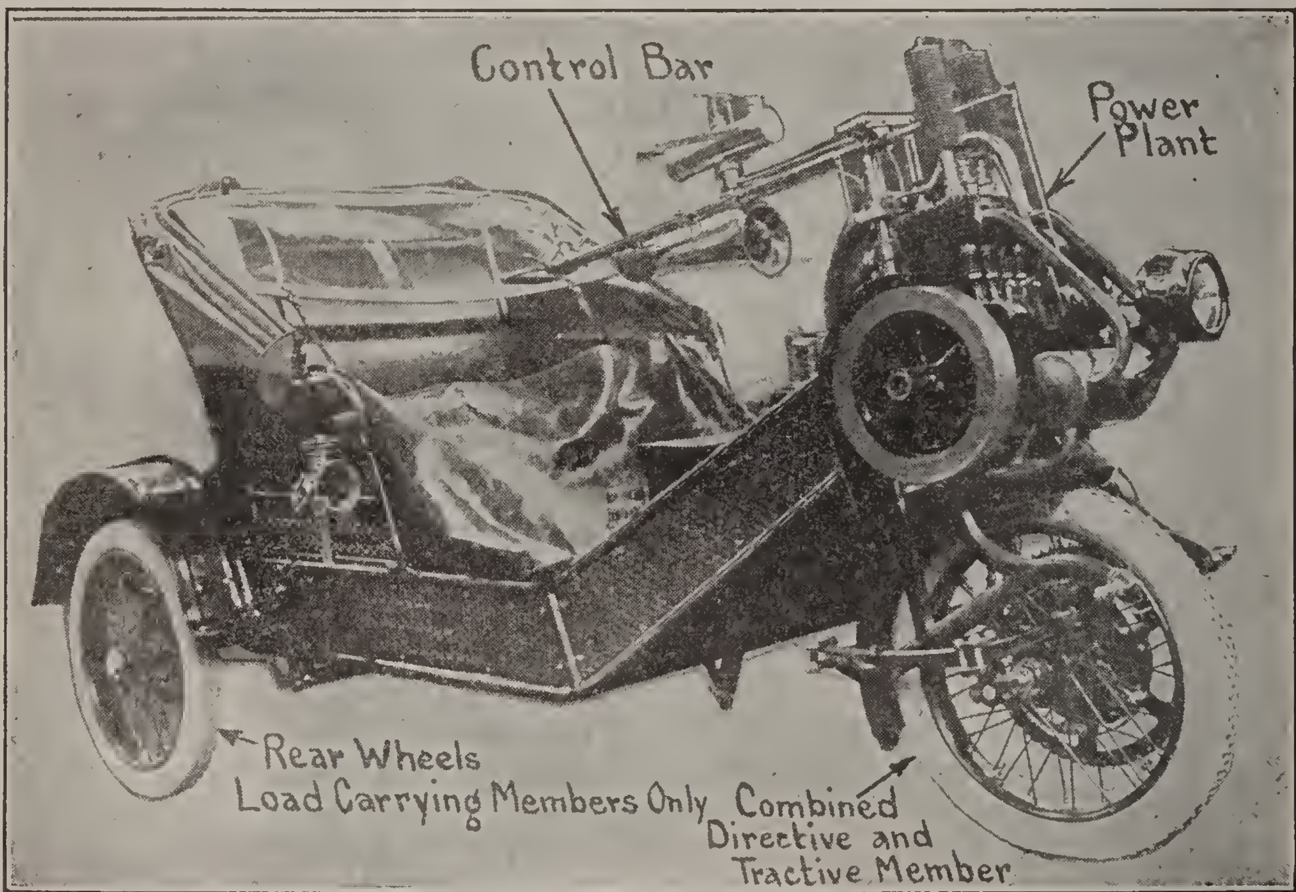


Fig. 283.—Three Wheel Cyclecar of German Design With Combined Directive and Tractive Member for Front Support.

country, was that the character of our highways did not favor a form of vehicle in which the two front wheels would follow the wagon track while the rear one would travel between them on that portion of the road traversed by the horses' feet. On soft roads such as were common in America several years ago before the widespread and almost universal use of the automobile promoted a general appreciation of the advantages of better highways, the objections to the three-wheel form were certainly based on practical experience and not mere theory.

The conditions abroad are much more favorable to tricar development because the highways are uniformly good, and are not apt to be rutty or have soft surfaces as in this country. Another thing that detracted from the popularity of the tricar form was its unconventional appearance as these did not seem to be either motorcycles or automobiles. This objection does not apply to the four-wheel cyclecars, because in most designs these resemble miniature automobiles or to the sidecar-motorcycle combination.

A typical tricar of English manufacture which has been used very widely in that country is shown at Fig. 280. This is known as the Morgan and is unconventional in several respects. One of these is in the method of carrying the power plant directly at the front of the chassis and ahead of the front axle. The drive from the engine is by a shaft to a countershaft through the medium of a pair of bevel gears, and on this countershaft are mounted positive clutches adapted to engage either of two driving chains which run to the single rear wheel, which serves as a traction member. Another popular English three-wheeler, known as the auto-carrier, is shown in the two-passenger form at Fig. 281. The side elevation and plan view at Fig. 282 show clearly the disposition and arrangement of the power plant and other components. The engine in this case is carried beneath the operator's seat and drives the rear wheels through a simple chain. A clutch and two-speed gear is incorporated in the rear hub. The design of the chassis presented is such that the space at the front end may be utilized to advantage for carrying parcels as there is sufficient room for a large carrying case.

An unconventional design of German manufacture that has been copied in this country but which has never been popular is shown at Fig. 283. This three-wheeler differs from the others described, in that the single front wheel serves both for steering and driving the vehicle. The two rear wheels revolve on a dead axle as in horse-drawn wagon construction, and are employed only as load-carrying members, though brakes are applied to drums carried by the wheel hubs. The engine is a two-cylinder four-cycle air-cooled form with external flywheel. It drives the front wheel through the medium of a large sprocket attached to the front hub. A clutch is interposed which is controlled by rotating the spade handle at the end of the steering

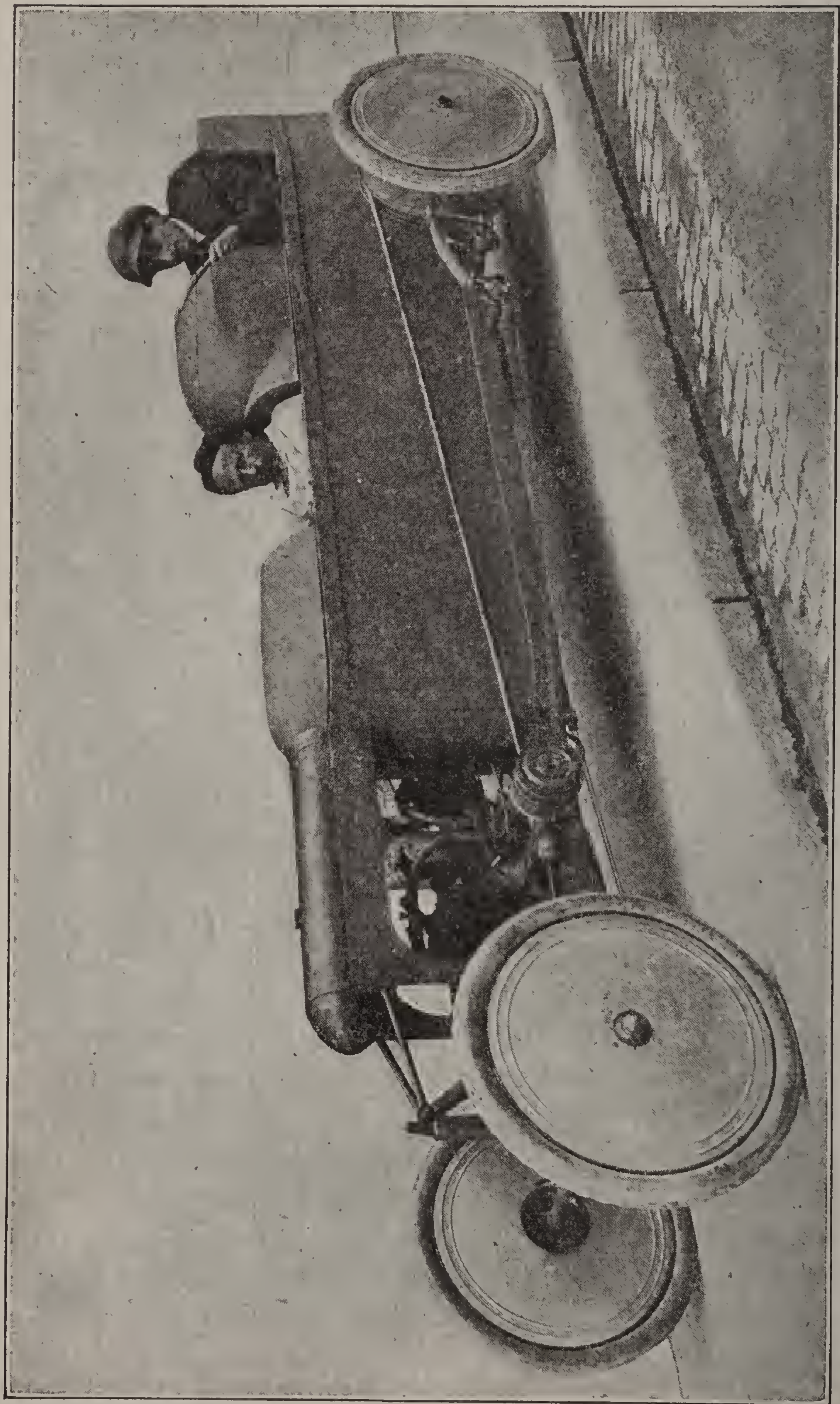


Fig. 284.—The Bedelia Cyclecar, the Original Four Wheeled Form Fitted Up for Racing.

tiller bar. If the handle is moved in one direction, the low-speed gear is engaged; if turned in the other, the high-speed is brought into engagement. Three control levers for the motor speed are carried just above the handle on the tiller bar, one of which is used to control the magneto, the other two to regulate the carburetor. About half way up the steering tiller or control bar, an oil tank is mounted to which a suitable pump is attached by which oil may be directed to the engine crank-case. While it would seem difficult to handle this combination, owing to the great amount of weight carried by the front wheel, the vehicle is said to steer easily, and to give very good service under severe operating conditions.

Typical True Cyclecar Forms.—The original cyclecar was designed to take the place of the motorcycle and sidecar combination that has been very popular in Europe, even more so than in this country. This as shown at Figs. 284 and 285, is known as the "Bedelia," and a model was built by M. Barbeau, of Paris, France, as early as 1910. This was a very small automobile driven by a motorcycle power plant. Its weight was less than 400 pounds, and it had a tread of 36 inches. The wheel-base was 100 inches, and, as it was very low, the passengers were carried very comfortably. It was made to accommodate two persons, the passenger being seated in front, while the driver sits over the rear axle. On the modern forms, the twin-cylinder motorcycle engine of about 8 horse-power is placed just behind the front axle, and drives a countershaft which is crosswise of the chassis under the passenger's seat by a roller chain. Pulleys of the motorcycle type suitable to take the regular V-belt are attached to the ends of the countershaft, and these impart motion to the large belt pulleys on the rear wheels by means of motorcycle belts.

An ingenious clutch action is obtained by drawing the rear axle forward when it is desired to stop the car, as this makes the belt run loose and enables the motor to turn without driving the wheels. A further movement of the hand lever brings the rear axle forward far enough so the belt pulleys engage fixed brake blocks or shoes which arrest motion of the wheels. The steering is by means of a wire-spoke hand wheel which turns the whole front axle through a drum on the steering shaft and a steel cable connection through pulleys. The

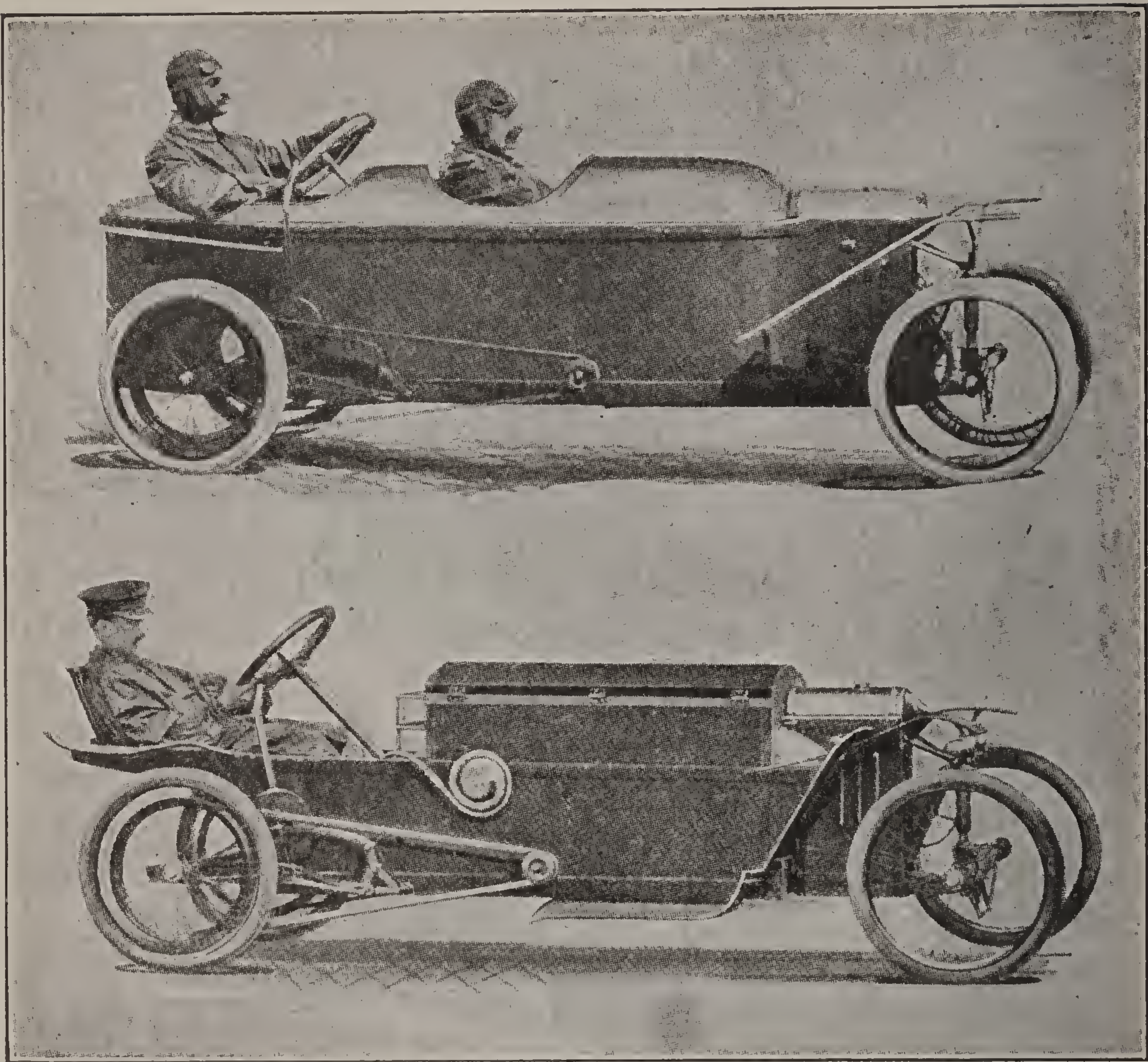


Fig. 285.—Two of the Regular Bedelia Models. Two Passenger Touring Type Above, Commercial or Light Delivery Design Below.

axle is hung at a central point in a steering head very similar to that of the motorcycle.

The first public appearance of the car was in a road race over a course 138 miles long, and this small vehicle surprised the public, and more so its inventor, by averaging 38 miles an hour the entire distance. The same car attained a speed of 55 miles per hour on a track. This resulted in a large demand for these cyclecars, and induced many manufacturers to enter the field.

A number of other designs that are patterned very closely after the Bedelia have been contrived. One of these, known as the "Automobilette," is shown at Fig. 286, and it will be evident that considerable space is available under the hood for housing a much more

pretentious power plant than the small engine used to drive the vehicle. This employs side-by-side seating. Practically the entire passenger weight is carried over the rear axle. The method of control is just the same as that used in the Bedelia, as the entire rear axle is moved to obtain a clutching action through varying the tension of the driving belt. The Super, another French cyclecar, is shown at Fig. 287. This design also involves the movable rear axle, and, with the exception of the seating arrangement, resembles the original Bedelia design very closely. The tandem seating arrangement is followed, but the positions are reversed from the practice established

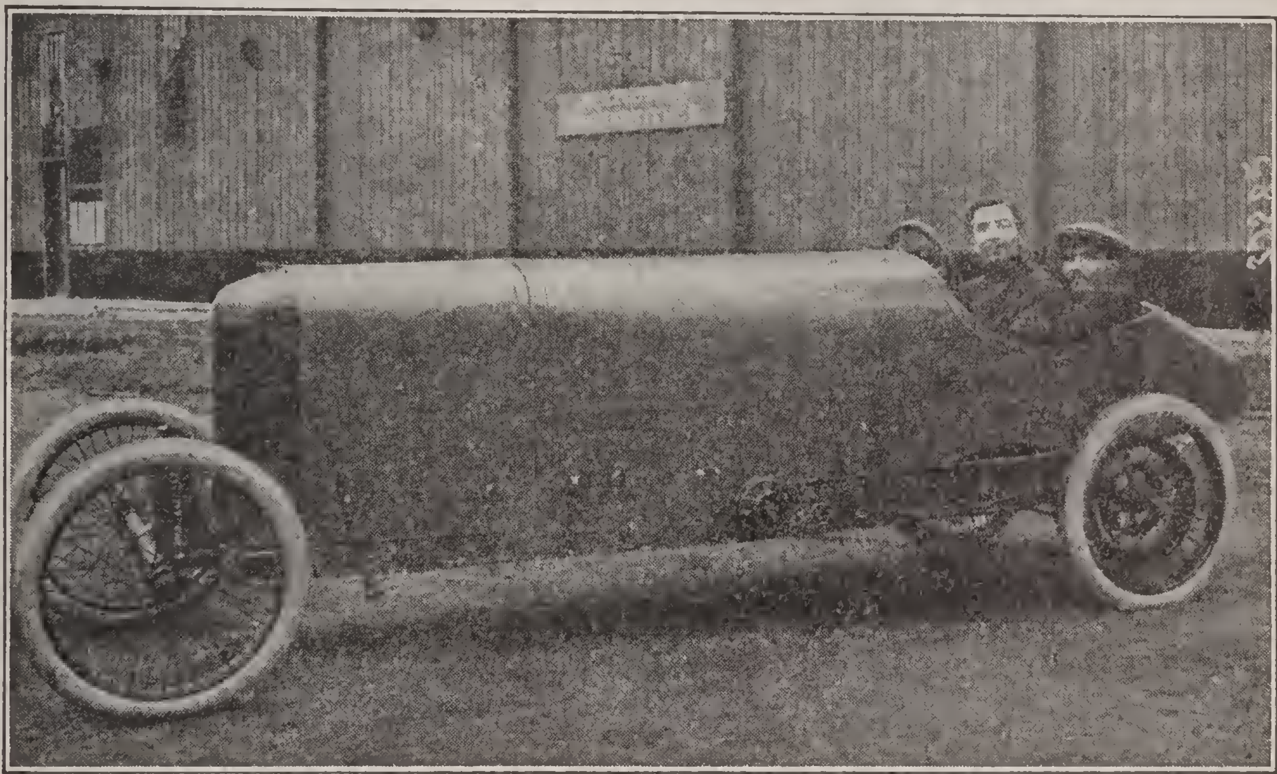


Fig. 286.—The Automobilette, a French Racing Cyclecar With Side by Side Seating Arrangement.

by the Bedelia. The driver occupies the front seat and the passenger the rear. A number of cyclecar designs showing the possible range from the three-wheel racing monocar to the form following very closely the lines of the average small automobile are illustrated at Fig. 288.

The tendency of some American designers is to follow closely established automobile practice in some forms except as relates to power and size of components. Other constructors believe that the cyclecar should be designed especially for the work it is to do and along dis-

tinctive lines that depart from conventional automobile practice. Two American cyclecars, shown at Fig. 289, are modified from current automobile practice. The one in the upper part of the illustration is an underslung construction in which the axles are mounted above the frame sides, while the one shown below it has the frame supported above the axles as in usual forms of motorcars. The cyclecar designs at Fig. 290 show a radical departure from the usual automobile, and, at the same time, do not ape the Bedelia as closely as do many of the foreign cars. The power plant is mounted in a different way, i. e., the crankshaft runs parallel with the frame side

Fig. 287.—The Super, a French Cyclecar Patterned After the Popular Bedelia Model Except That Driver Occupies Front Seat.

members, and the variable speed feature is obtained by a friction change-speed gearing. Drive to the rear wheels is by short belt instead of the longer members used on the original cyclecar. The model shown at the top is a two-passenger touring form, while the light delivery type is clearly depicted below it. Two cyclecars built on simple lines are shown at Fig. 291. In both of these, the long driving belts that are a feature of the original, or Bedelia type, are retained, but the drive is through a friction transmission in both cases, which provides a combined clutching and variable speed feature. While tandem seating is employed, the driver is seated at the front and the

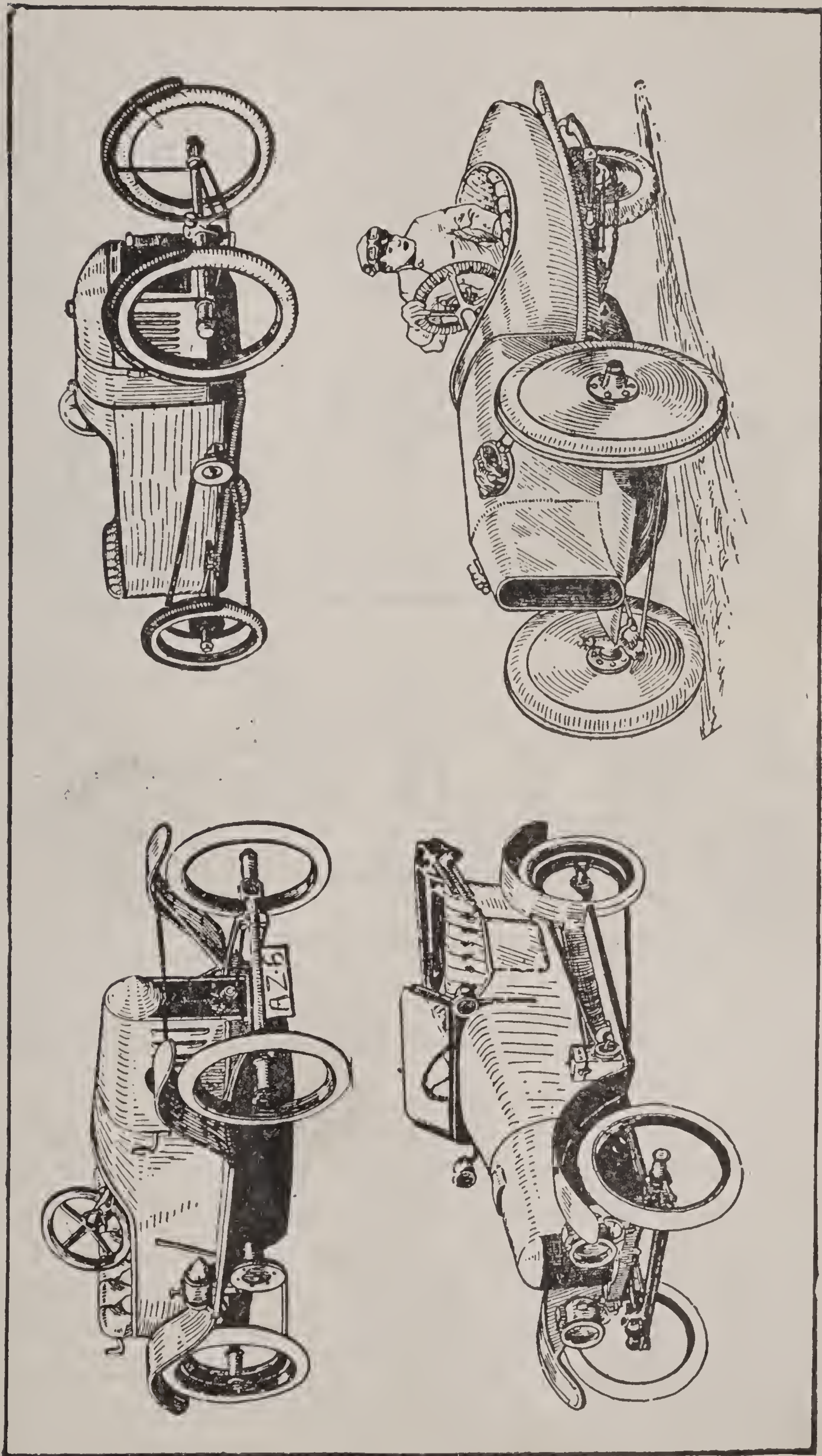


Fig. 288.—Typical Cyclecar Designs That Have Proven Practical.

passenger at the rear, which seems to be the general trend in this country.

Seating Arrangement.—Some designers who do not favor the tandem seating that is a feature of many cyclecars, have endeavored to apply the side-by-side seating that is the rule in automobiles. While it is not difficult to provide a seat of ample size to take two and even three people in a body of standard width adapted for the 56-inch tread chassis, it is somewhat of a problem to obtain side-by-side seat-

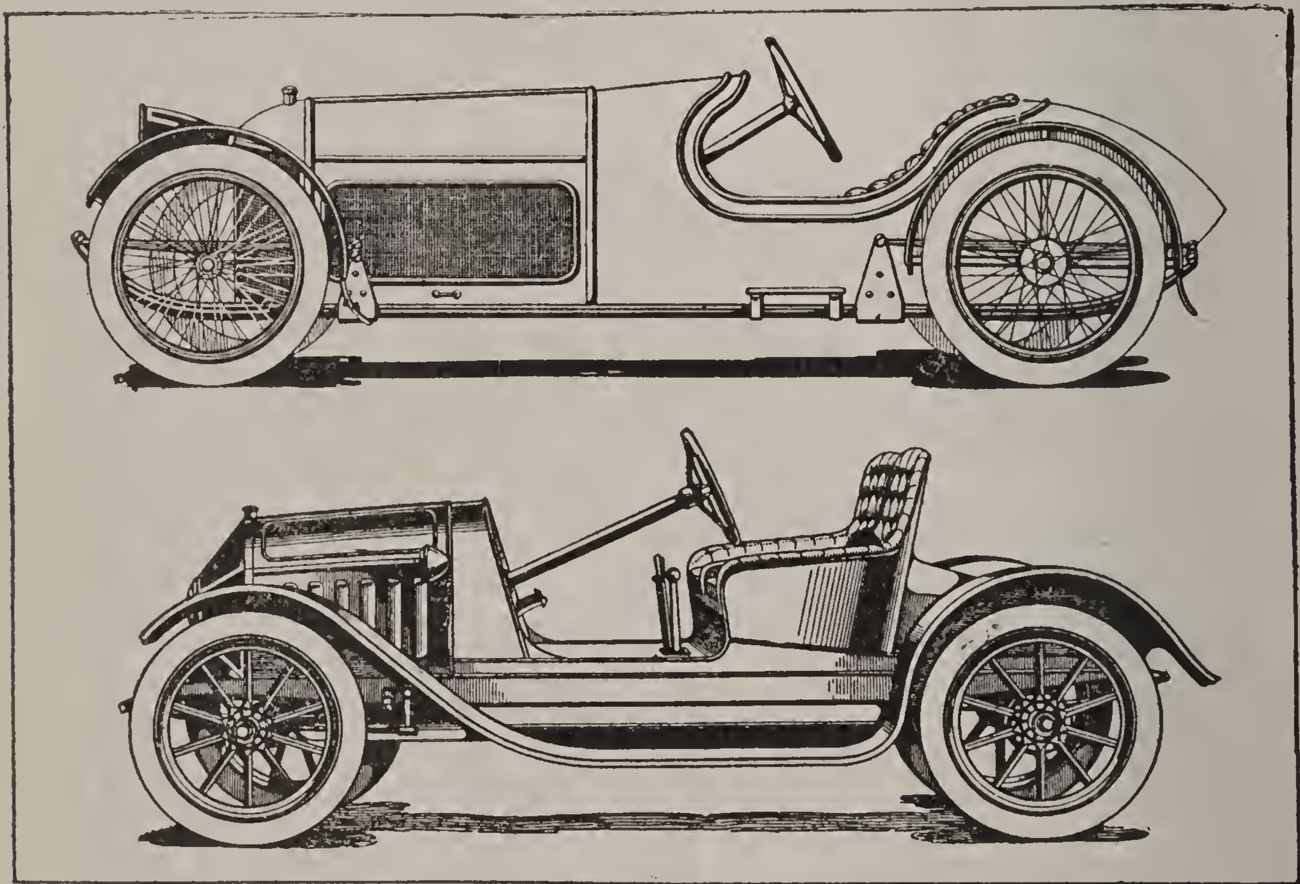


Fig. 289.—Examples of American Cyclecars Following Automobile Lines on a Smaller Scale. Above, the Lavigne, Below, Detroit Speedster.

ing with the narrow tread that prevails on most cyclecars. A 36-inch tread does not permit of a body much wider than 26 or 28 inches, and the seats must be narrow unless the body is allowed to overhang the wheels or project on the sides. The arrangement shown at Fig. 292 is one method of carrying two people without unduly increasing the body width. The tandem seating that has been such a feature of the Bedelia cyclecar is shown at Fig. 293. In this, the passenger is carried ahead of the operator which is reverse to the general practice in England or this country. There is one disadvantage of moment

in using wide bodies, and that is the factor of air resistance, which means that more power will be consumed than where there is less exposed area as when one passenger is carried behind the other. As has been previously explained, the factor of air resistance is an important one that cannot be neglected, especially at speeds over thirty miles per hour. The seating arrangement that permits of minimum air resistance is the best for the simple form of cyclecar, because the

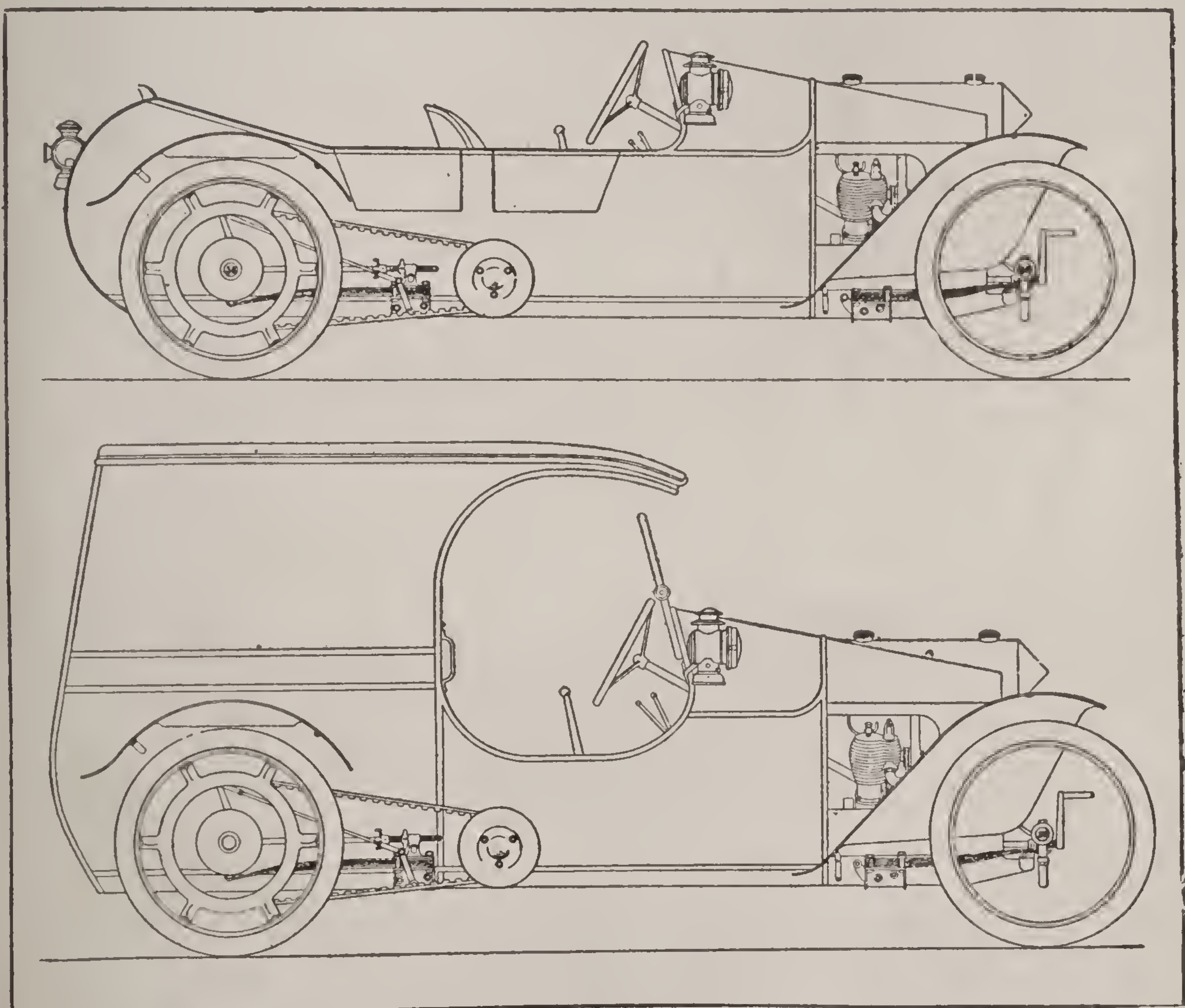


Fig. 290.—Two Models of the Scripps-Booth Cyclecar. Touring Model at Top, Below, Commercial Type.

power plant may be of lower capacity to attain the same speed a larger engine would provide in a wide body design.

Advantages of Narrow Tread.—The first Bedelia type cars built in England were patterned very closely after the original design, but very soon the demand was for more artistic body designs and more luxury, so that at the present time many of the vehicles produced in

England that are called cyclecars are really small automobiles that sell as high as $1,000, although they still retain the narrow tread, which is considered a feature of decided advantage, inasmuch as it permits the cyclecar to be housed in a small shed, and avoids the necessity of special full-size garage facilities. It is claimed that the 36-inch tread construction is not suitable for American roads, because it will not track with other vehicles which use the standard tread of 56 inches. It is, of course, admitted that the main highways of Continental Europe, and of England, have exceptionally good road surfaces.

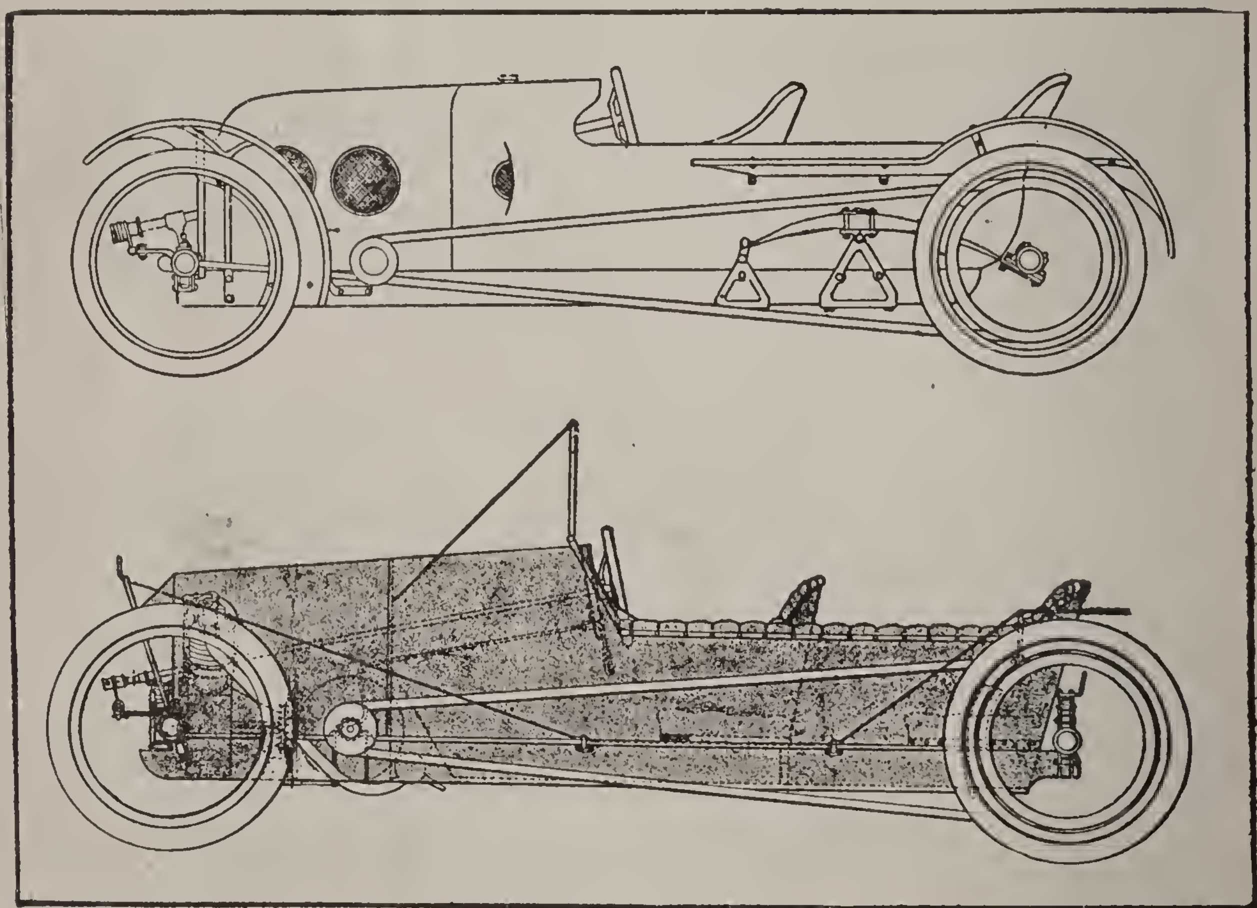


Fig. 291.—Two American Cyclecar Designs Employing Long V Belt Drive. At Top, Malcolm, Below, the Imp.

In France, however, where the first cyclecars were produced, there are plenty of byways with ruts worn by traffic, which, while perhaps not as bad as the majority of country roads in America, offered ample opportunity to test the practicability of the narrow-tread cyclecar. As there has been no change in the tread of the Bedelia in 3 or 4 years, and as the narrow tread has been continued by other French and English designers, it is apparent that the narrow tread gave satisfactory service. The usual width of the road ruts in America is 7 or

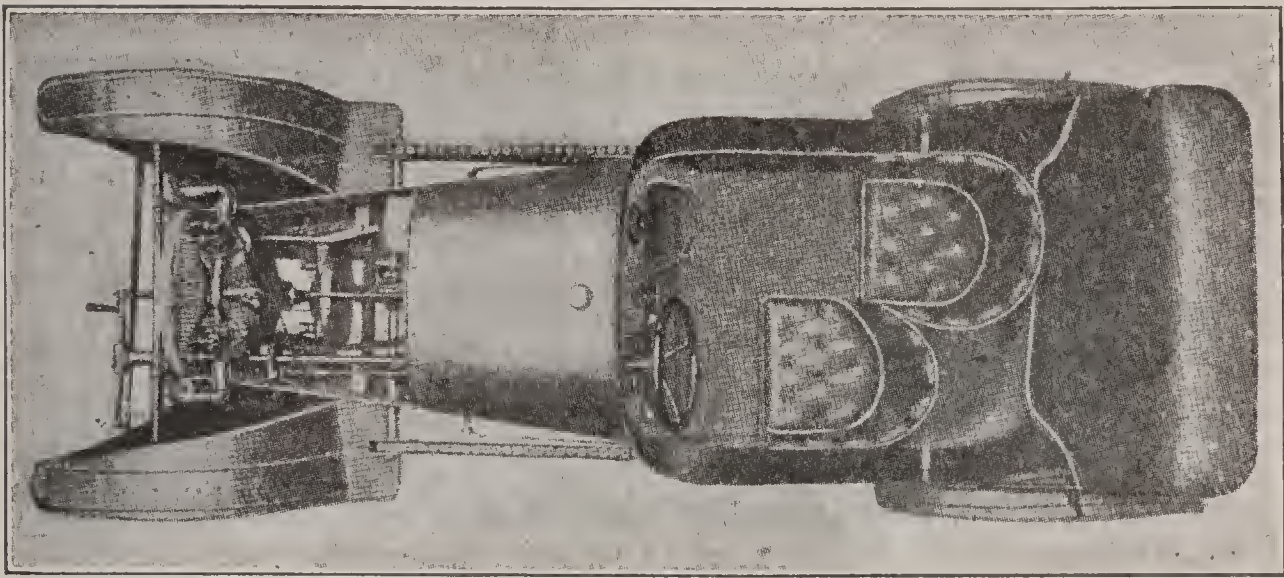


Fig. 292.—Plan View of the Pioneer Cyclecar, Showing Side by Side Arrangement of Seats.

8 inches and they are 56 inches apart, which means that there is approximately a space of 42 inches between the wheel tracks, which should be ample to allow a vehicle of 36-inch tread to pass between them.

Cyclecar Chassis Design.—In vehicles of the light car or automobile type, there is not much difference in the general arrangement of parts of the chassis than that prevailing in the larger vehicles. This is clearly outlined by the two chassis types shown at Fig. 295.

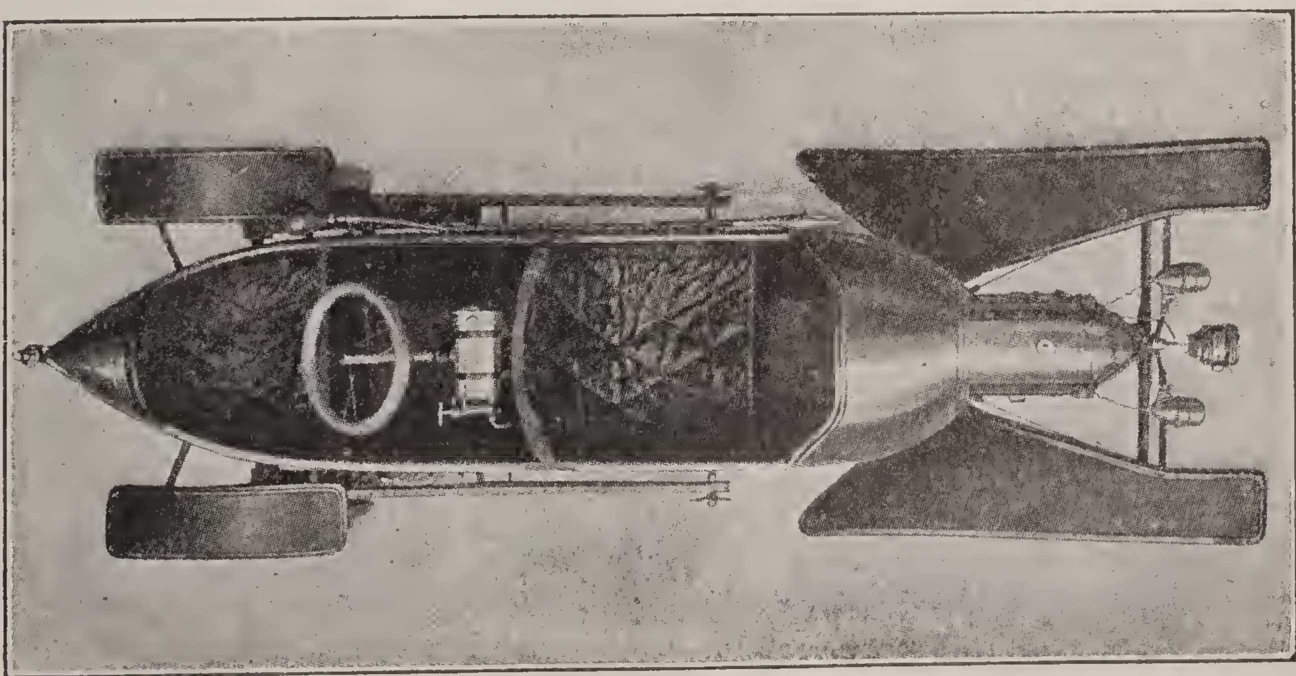


Fig. 293.—Top View of the Bedelia Cyclecar, Showing Tandem Seating Arrangement.

Anyone familiar with automobile practice can see that in the placing there is very little difference except for the size of the parts. The location of the power plant, change-speed gearing, and method of final drive to the live rear axle, is the same. The motor is placed at the front of the chassis. In one case, the gear box is carried about midway between the wheels, while in the other it forms part of the unit power plant. The final drive is by means of propeller shaft to bevel gearing in the rear axle. A true cyclecar chassis is shown at Fig. 296. In this, the power plant which is a twin-cylinder air-cooled motor rated at 12 horse-power drives a friction disc through a shaft connection. A friction wheel is mounted on the cross shaft, and is adapted to be

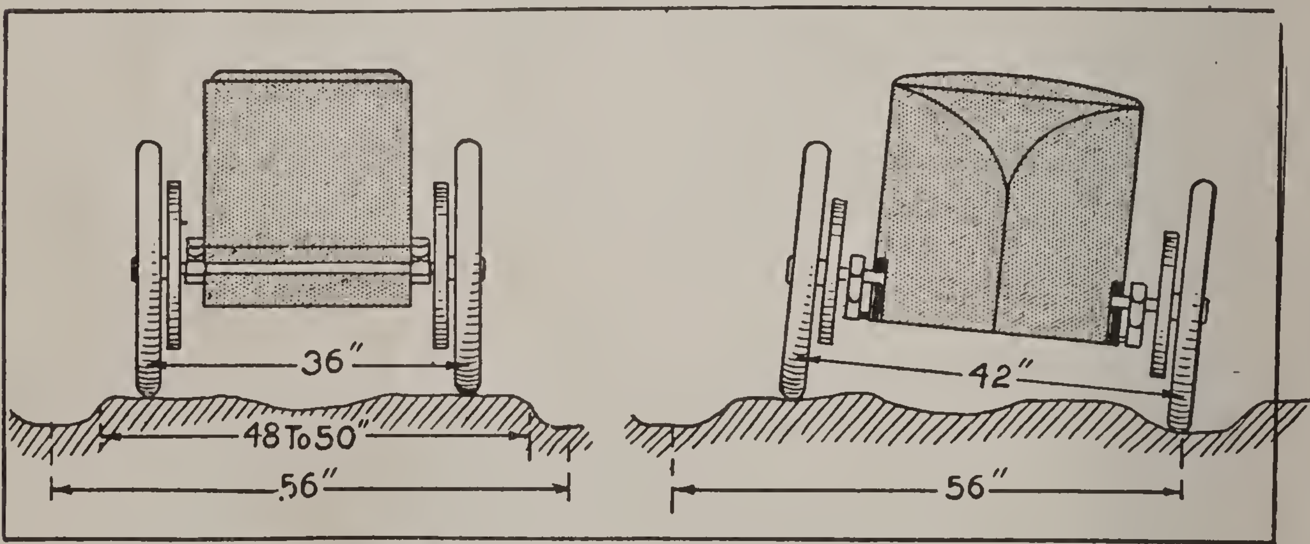


Fig. 294.—Diagrams Showing Desirability of Narrow Tread in Permitting Cyclecar to Run Between Ruts Made by Vehicles With Standard Tread.

moved back and forth across the face of the friction disc. The final drive is by means of belts to the rear wheels revolving on the fixed rear axle. The chassis at Fig. 297 does not differ essentially in principle from that previously described, except that a four-cylinder water-cooled motor is used and final drive to the rear wheels is by roller chains.

Cyclecar Power Plants.—The type of power plant utilized in cyclecar propulsion depends entirely upon the nature of the vehicle. For instance, the simple type or true cyclecars use motors patterned after forms that have received general application in motorcycle service, while the light cars or those which follow automobile practice more closely employ water-cooled motors, usually of the four-cylinder

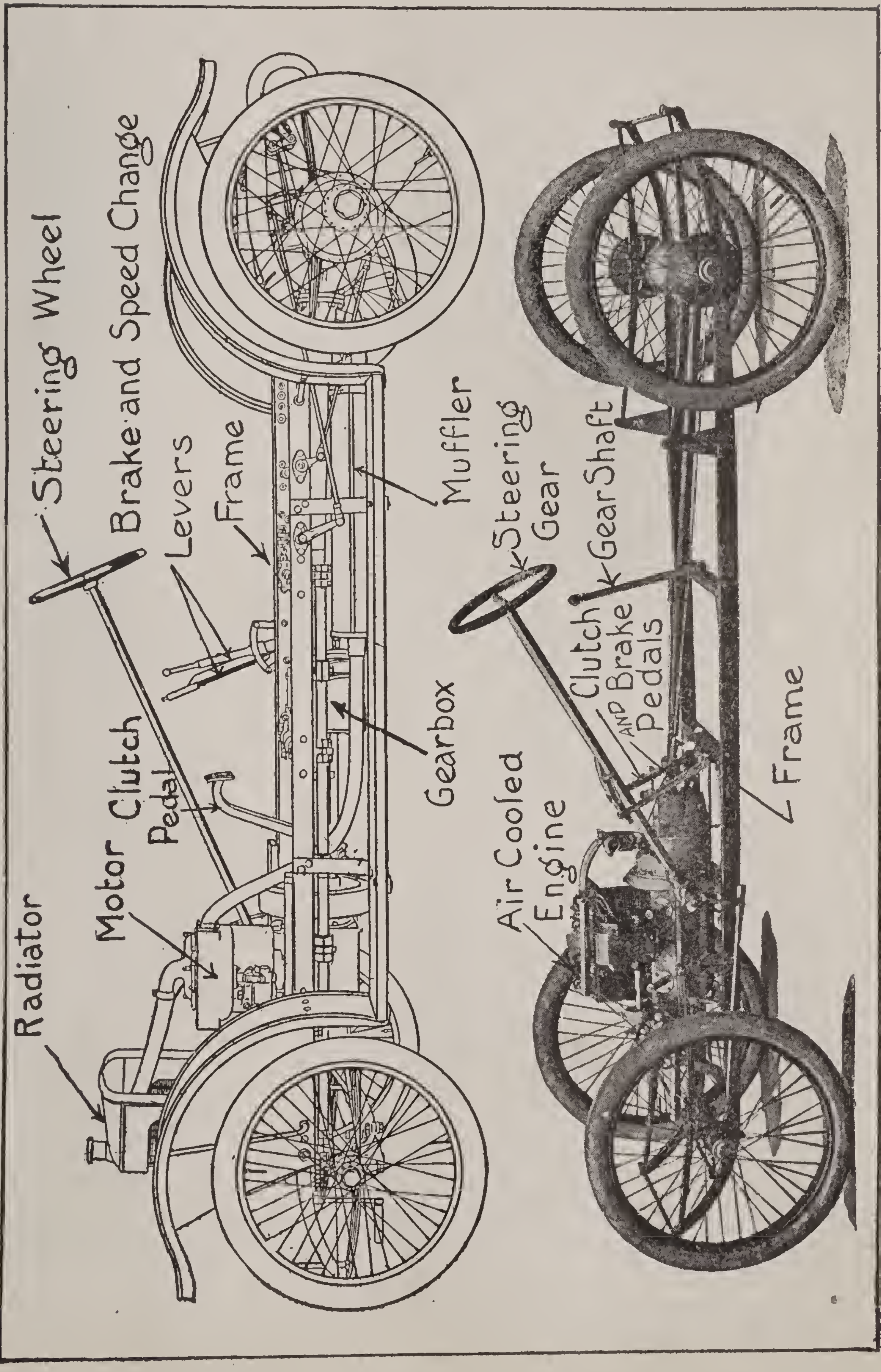


Fig. 295.—Two Methods of Chassis Suspension Used in Cyclecars and Light Cars. At Top, Chassis Supported Above the Axles, Below, the Lavigne Underslung Design.

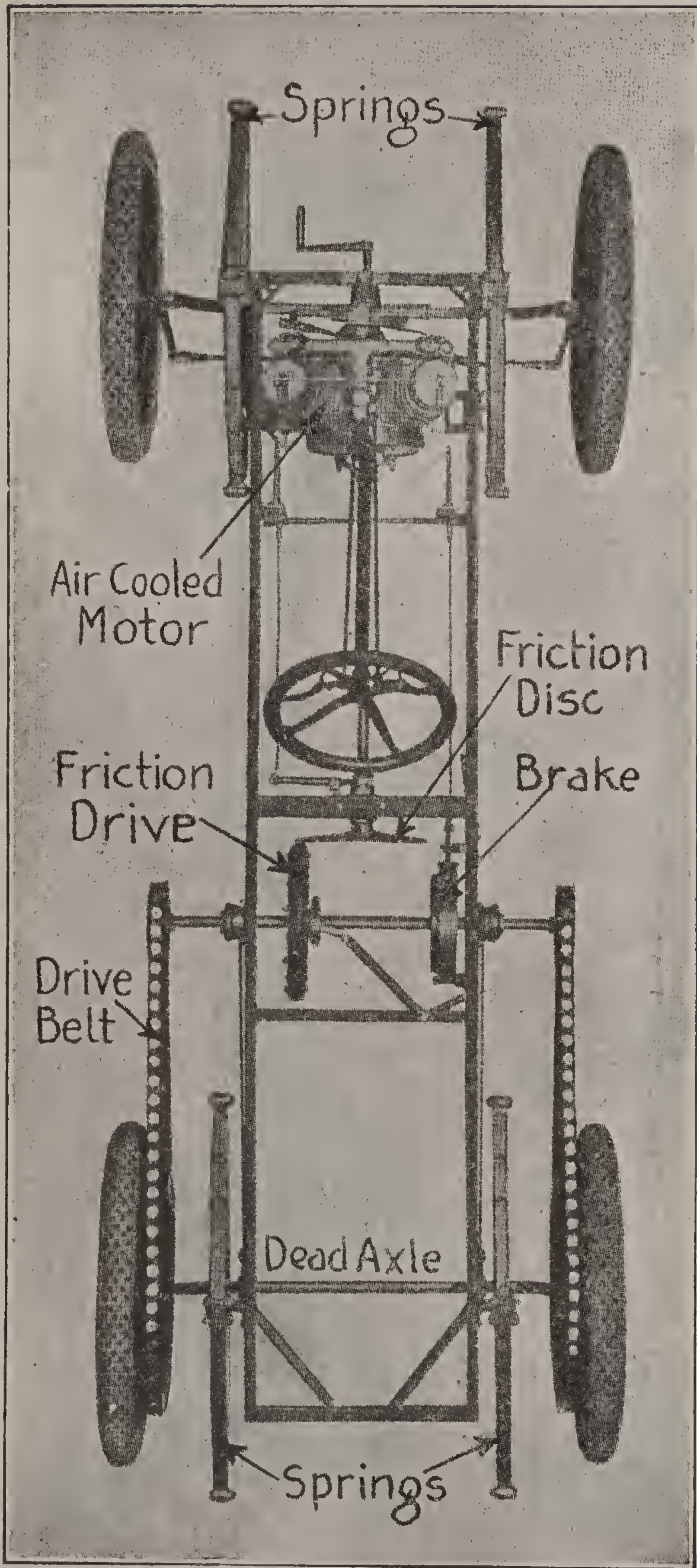


Fig. 296.—Chassis of the Merz Cyclecar, Showing Arrangement of Parts and Substantial, Simple Design.

type. The engine shown at Figs. 299 to 301, inclusive, is a two-cylinder form that will develop about 12 horse-power at a speed of 2,500 revolutions per minute, and follows motor-bicycle practice very closely, in that it employs two air-cooled cylinders, disposed one each side of the crank-case center line at an angle of about 22½ degrees with the crank-case center line, or one might say that the two cylinders had an included angle of 45 degrees. As is common with the light engines used in motorcycles, the inlet valves are mounted above the exhaust valves, and are operated by tappet rods and rocker arms, whereas the exhaust-valve stems are actuated directly by the usual form of push rods. In order to make for steady running, the motor is provided with an outside fly-wheel in addition to the balancing members mounted inside of the enclosed crank-case. To insure adequate

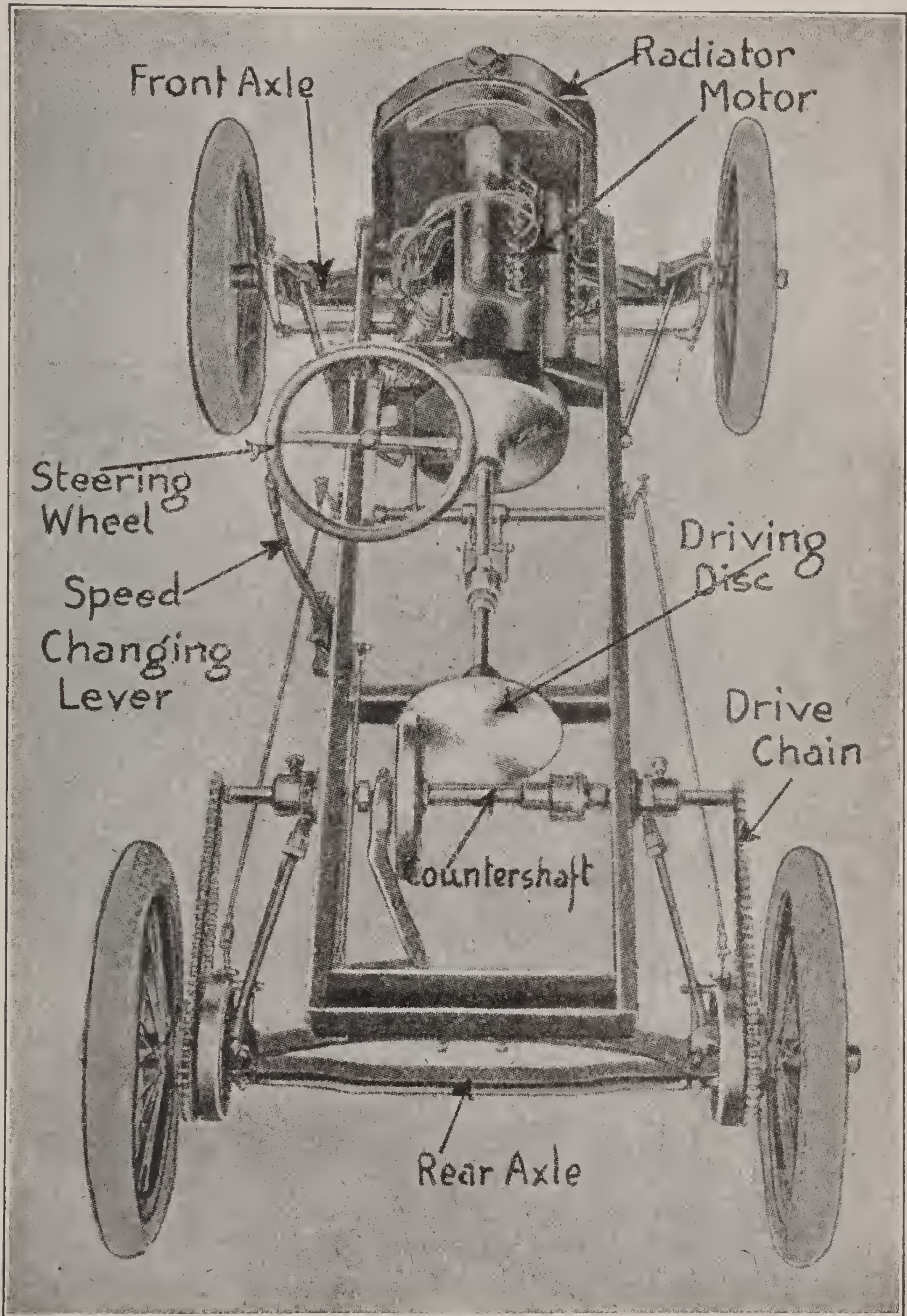


Fig. 297.—Plan View of the Trumbull Light Car Chassis, Showing Friction Change Speed Gearing and Double Side Chain Drive.

cooling when the vehicle is standing still, a two-blade fan directs a current of air against the cylinders. Ignition is by high tension magneto and the weight of the entire power plant, including magneto, carburetor, external fly-wheel, and cooling fan, is but 100 pounds. This type of motor is efficient, fairly well balanced, and powerful enough for the simple form of cyclecar that does not weigh over 500 or 600 pounds. It will propel such vehicles at speeds up to 50 miles per hour without difficulty, and is very economical of fuel, inasmuch

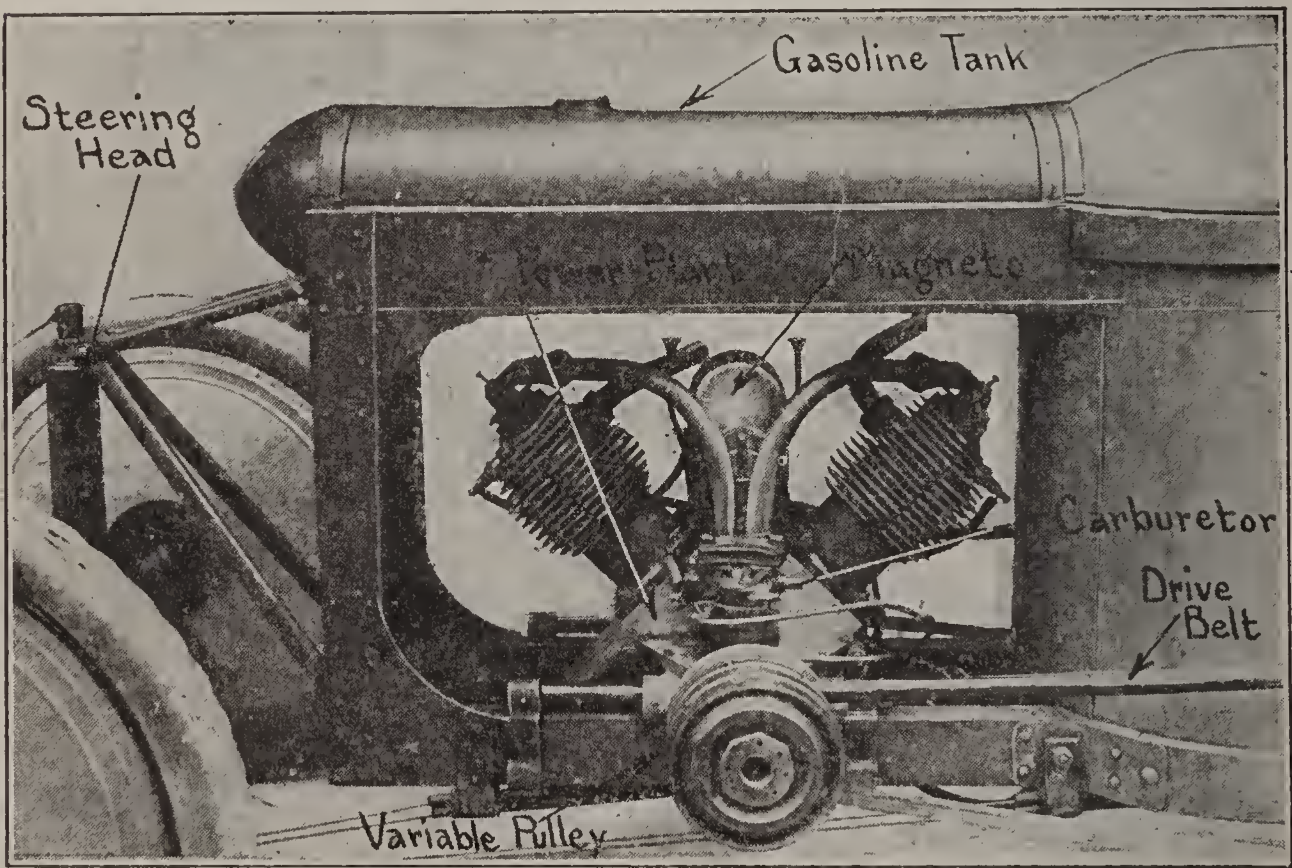


Fig. 298.—Showing Method of Placing 90 Degree Twin Motor Employed in Bedelia Racing Cyclecars. Note Direct Drive From Variable Pulleys on Engine Crankshaft.

as one gallon of gasoline will serve for 50 miles, if the carburetor is properly adjusted.

When the simple motorcycle forms of two-cylinder engines are used, in order to facilitate starting, decompressors are added to the cylinders which relieves the high compression, and thus makes it easier to crank the motor. These decompressors operate on a different principle than those ordinarily used in motorcycle practice where the exhaust valve is raised and a portion of the charge allowed to escape through it.

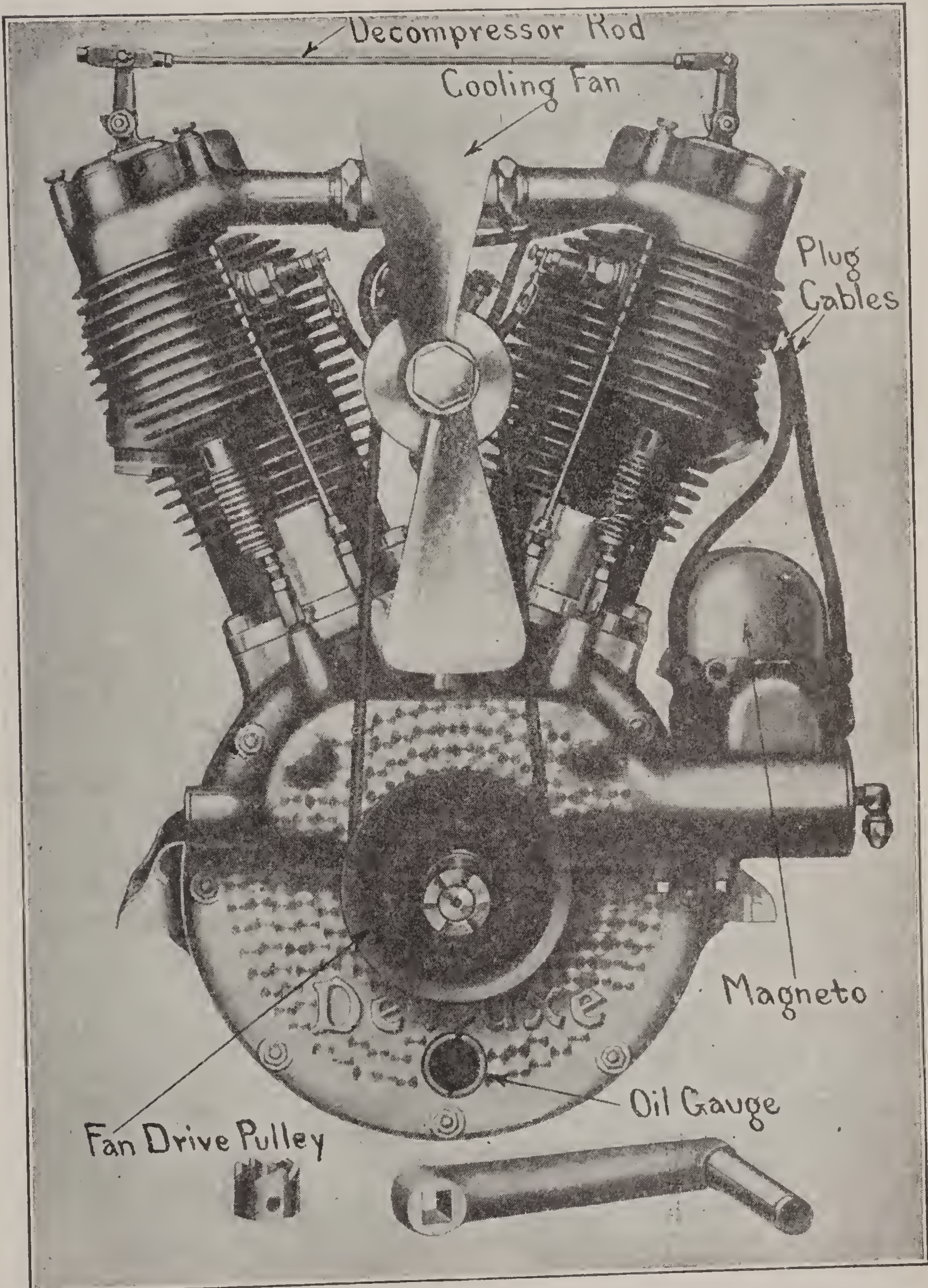


Fig. 299.—Front View of the Spacke De Luxe Twin Motor for Cyclecars. This Power Plant Follows Motorcycle Practice.

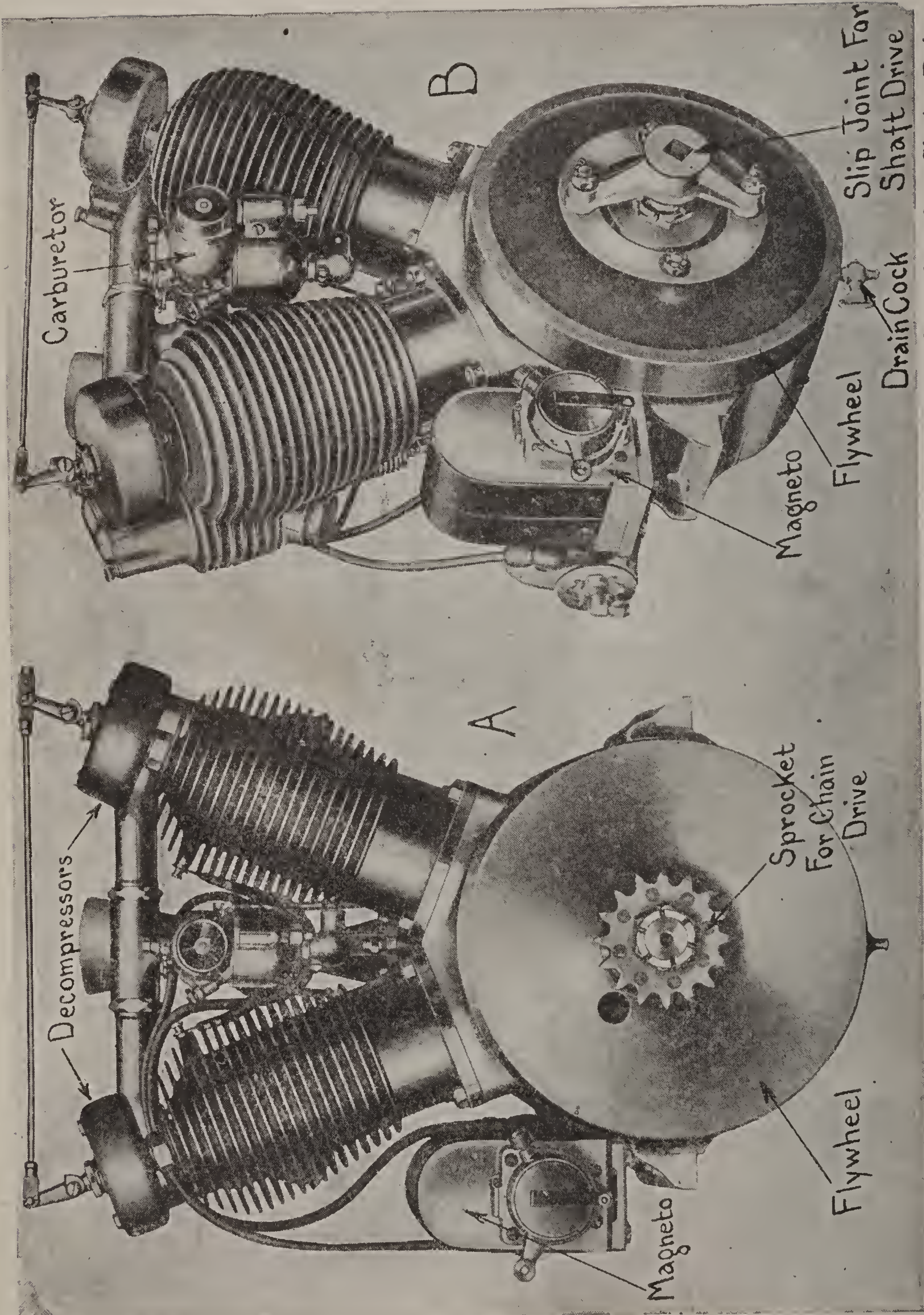


Fig. 300.—Drive Side of the Spacke De Luxe Cyclecar Motor. A—With Sprocket for Chain Drive. B—With Slip Joint for Shaft Drive.

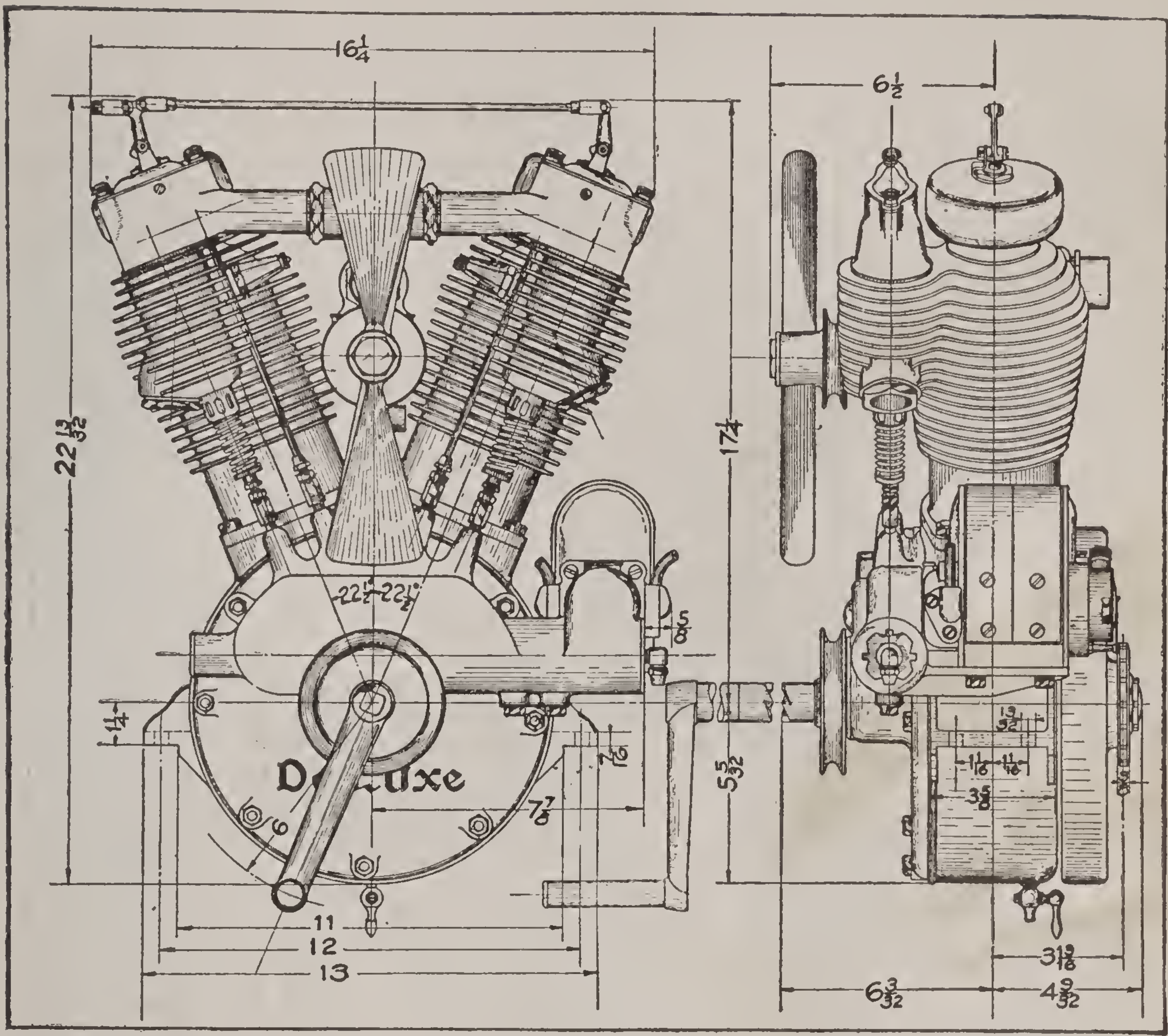


Fig. 301.—Diagram Giving Principal Dimensions of Spacke De Luxe Cyclecar Motor.

They consist of a chamber screwed to the cylinder head, having a valve at the lower portion that may be opened by moving a suitable cam lever that is in contact with the upper part of the valve stem. These act to increase the compression space, and provide an auxiliary chamber that fills with gas. This is not wasted as it is drawn back into the cylinder on the next intake stroke.

The motors intended for cyclecar propulsion are provided with two methods of drive. In the form shown at Fig. 300, A, the motor is intended to be placed in the frame of a cyclecar in just the same manner as it is arranged in the motorcycle, i. e., one cylinder behind the other. In this case, a sprocket for roller chain drive is attached to the fly-wheel. If the motor is to be placed transversely in the frame, as when friction drive is employed, a slip joint is provided in

which a squared end of the driving shaft will fit. This permits of a back and forth movement of the shaft and yet insures that the drive member must turn positively. The dimensions of a typical American cyclecar motor showing the compactness and accessibility of this very efficient power plant are given at Fig. 301. Two-cylinder motors of the V-type used abroad are often of the water-cooled form as shown at Fig. 302. A two-cylinder opposed motor of the air-cooled form adapted for cyclecar and light car propulsion is shown at Fig. 303, and the smooth running qualities of this type of power plant should make it very popular when its good features are properly appreciated.

In the cyclecars of the automobile type, the usual form of four-

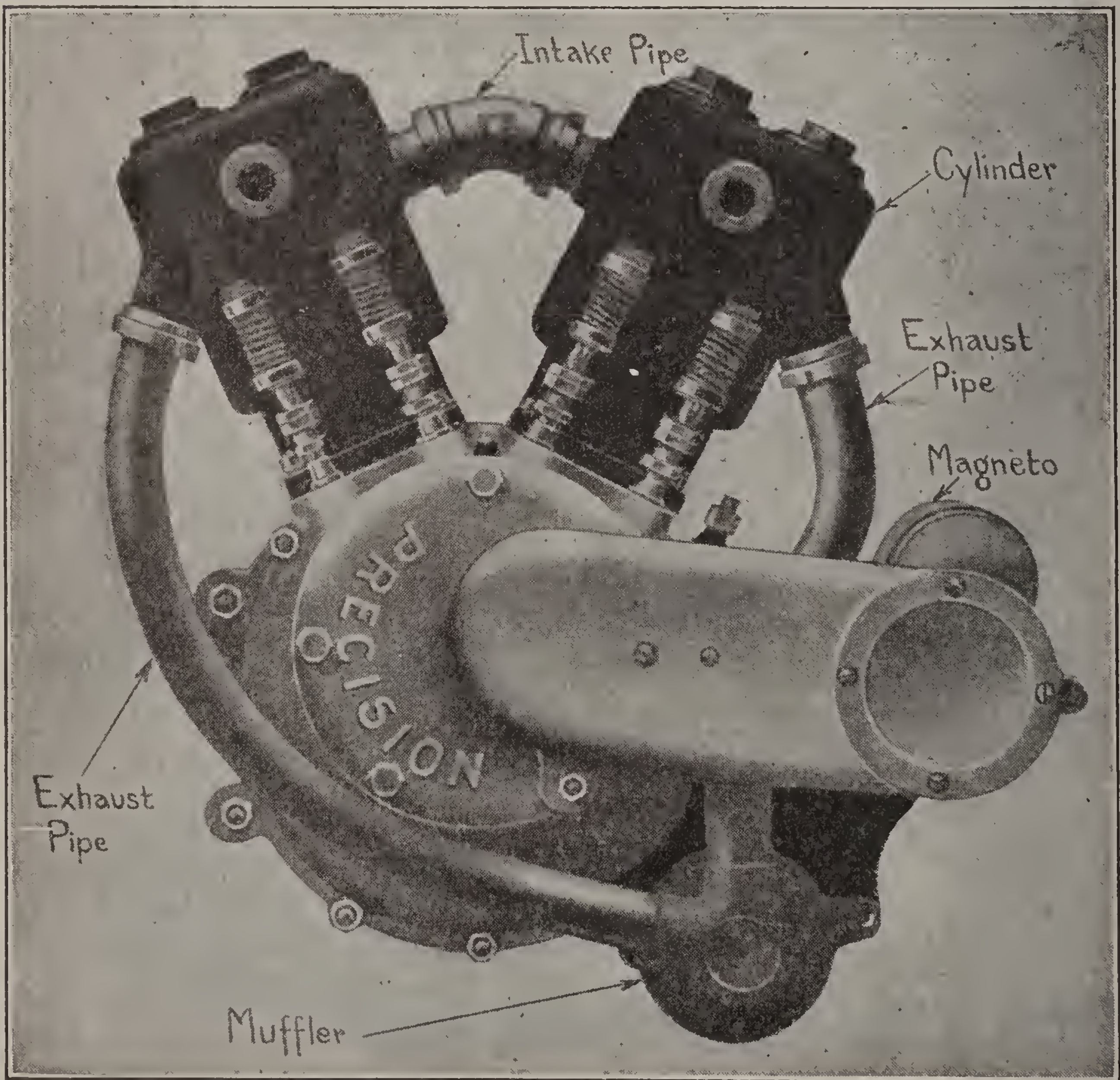


Fig. 302.—Twin Cylinder Cyclecar Motor of Precision (English) Design With Water Cooled Cylinders.

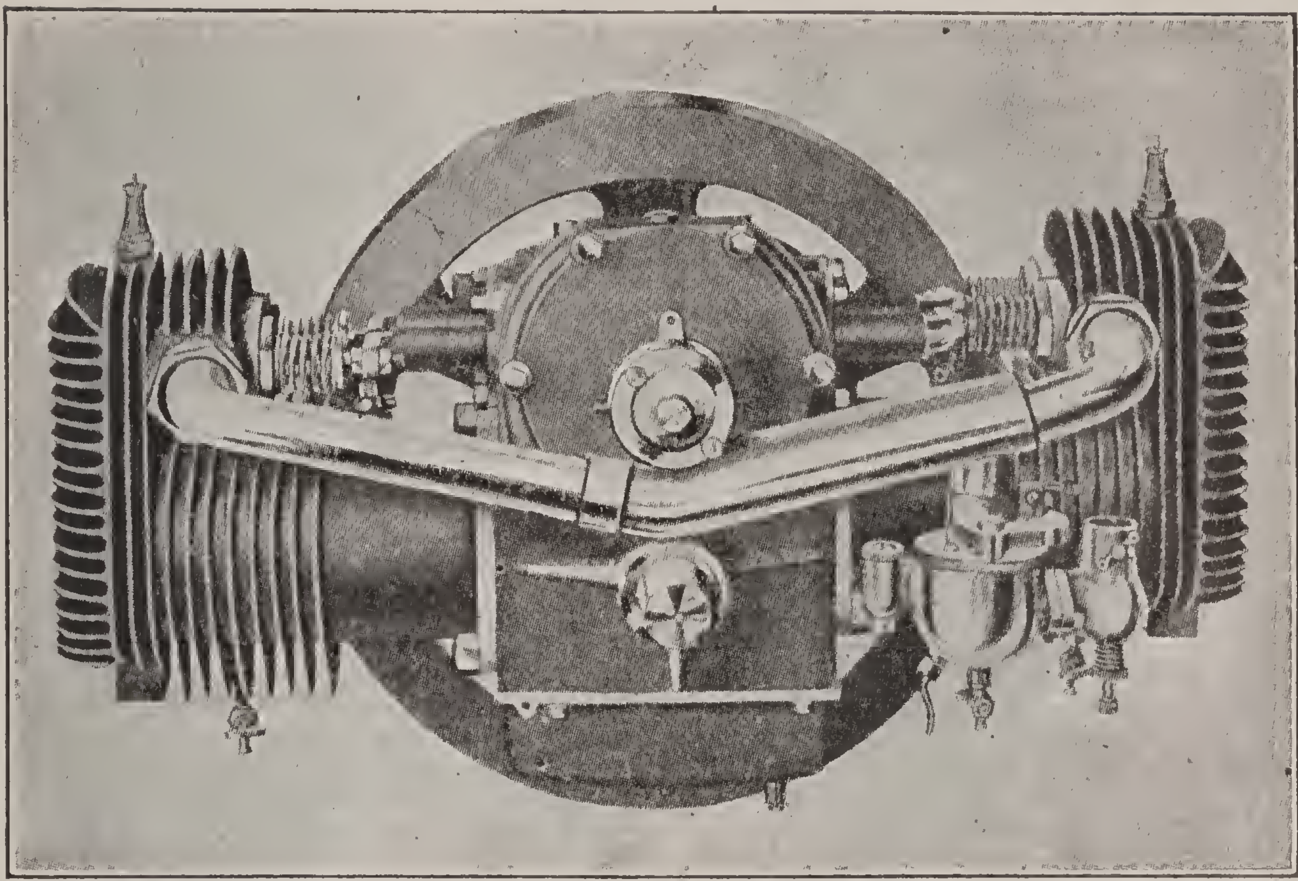


Fig. 303.—Double Cylinder Opposed Air Cooled Motor Adapted for Cyclecar Propulsion.

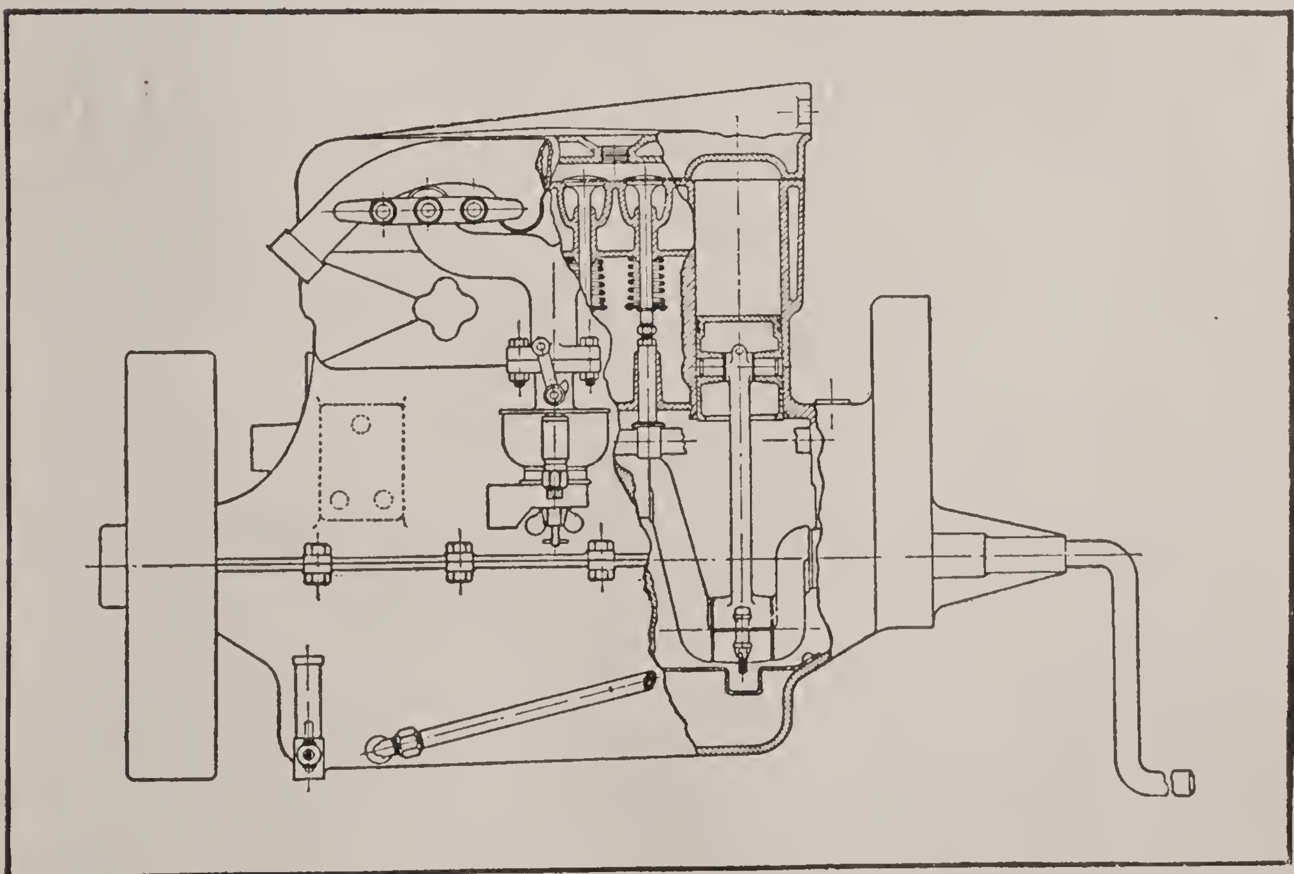


Fig. 304.—Sectional View of Typical Four Cylinder Water Cooled Power Plant for Light Cars.

cylinder water-cooled motor such as shown at Fig. 304 may be used, but the writer does not propose to consider this form to any extent because they are practically automobile power plants and follow the rules of practice established by automobile designers rather than motorcycle principles which we aim to describe in this treatise. Complete exposition of the automobile in all its forms will be found in "The Modern Gasoline Automobile," another of the writer's works.

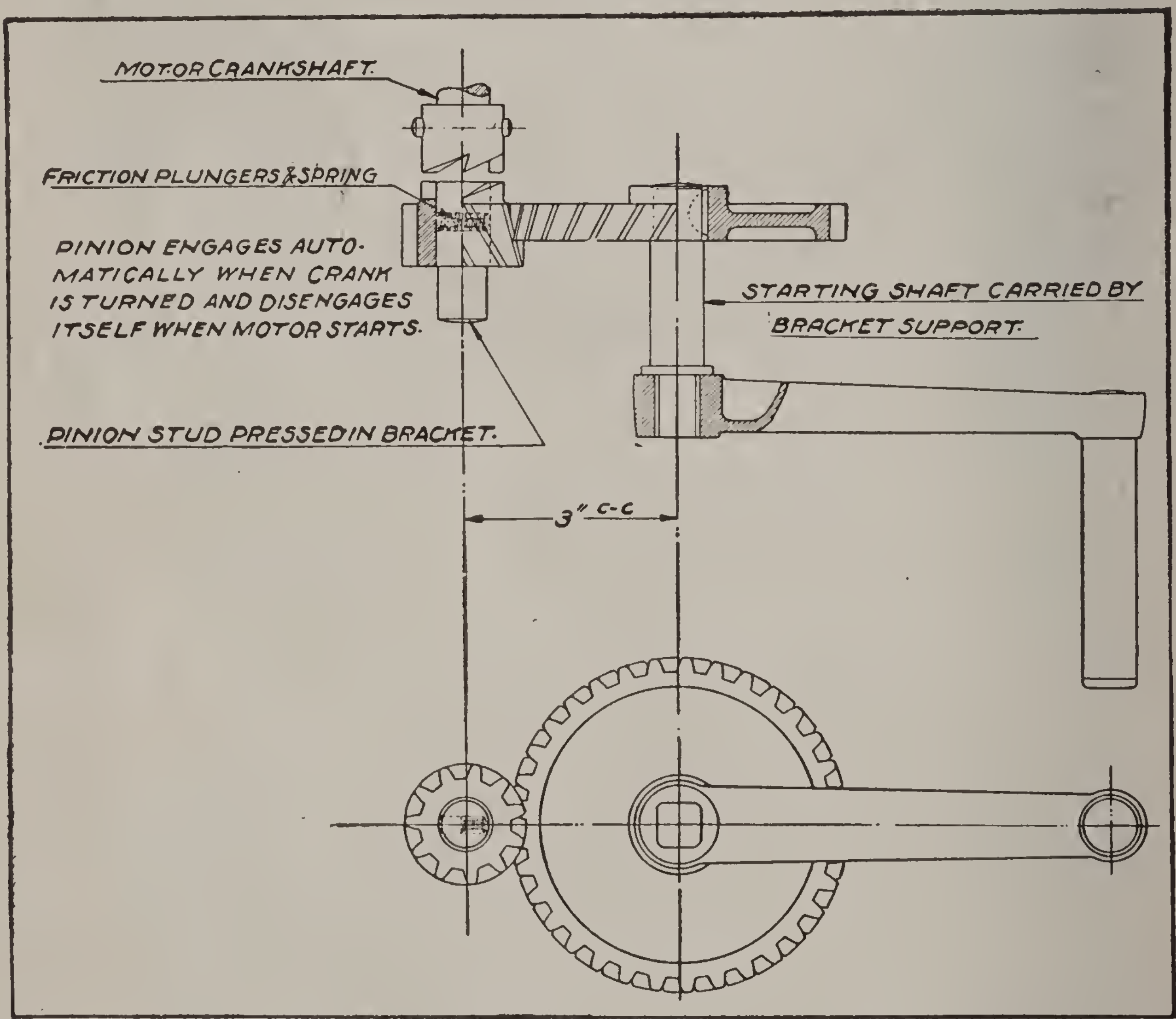


Fig. 305.—Spacke Geared Up Starting Crank to Facilitate Prompt Starting of Twin Cylinder V Motors.

As considerable difficulty is obtained in cranking the V-type of motor sufficiently fast to induce prompt starting when the starting crank was applied directly to the motor crankshaft, the geared-up construction, shown at Fig. 305, has been devised to turn the engine over at a high rate of speed without revolving the starting handle unduly fast. Another good feature of the angular teeth is that the

pinion will engage automatically when the crank or starting handle is turned and will release promptly as soon as the motor starts.

Cyclecar Change-Speed Gears.—A form of change-speed gearing that has been widely applied on cyclecars, because of its simplicity and cheapness, as well as ease of operation, is shown at Fig. 306. In devices of this form, one is enabled to obtain a combined clutching and change-speed action without much complication. The engine shaft is coupled to a driving disc of aluminum or cast iron which may be moved back and forth to contact with a driven wheel on a cross shaft. The drive is by frictional contact between the two discs, the

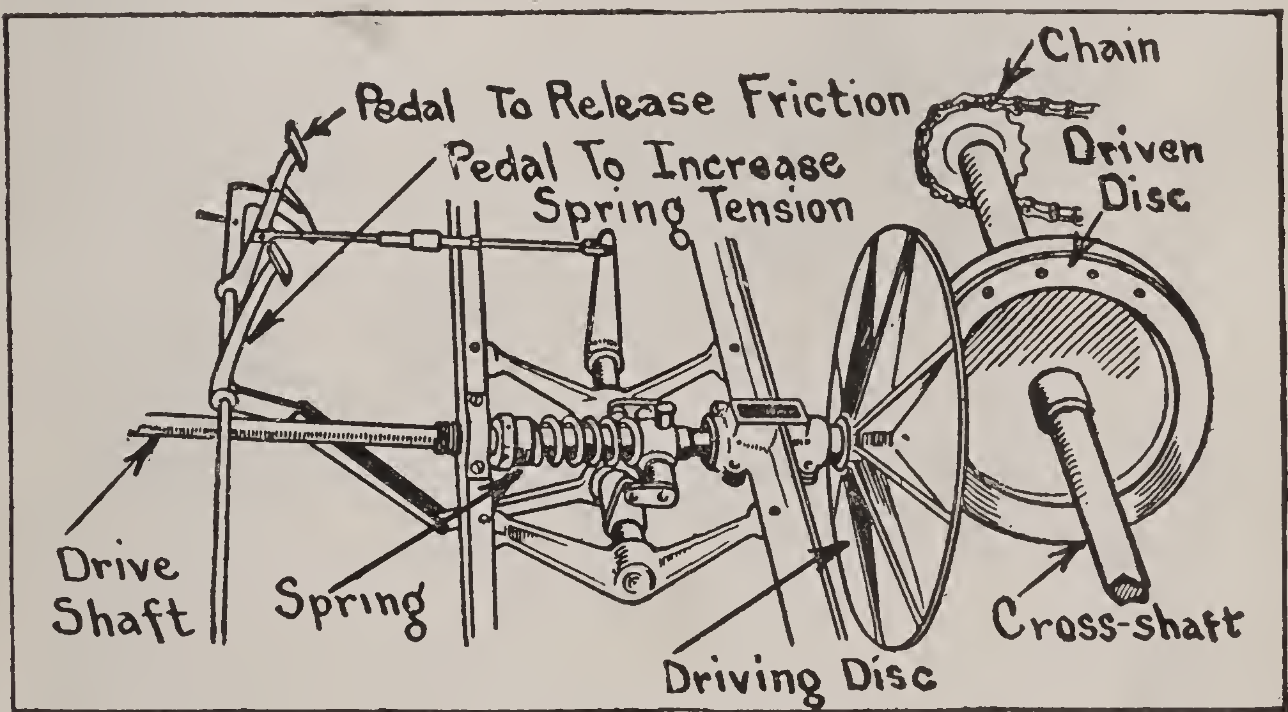


Fig. 306.—Arrangement of Friction Change Speed Gearing Used in Many Cyclecars.

clutching action is obtained by bringing the discs together while the speed-changing function depends on the position of the driven disc to the center of the driving member. The nearer the center the driven disc is placed, the slower the speed of that member because it is contacting with a smaller circle on the driving face of the disc turned by the engine. If the friction driven disc is moved to one side of center, a reverse motion will be obtained. Just the other side of center from the reverse will be the slow speed position. The speed then increases as the driven disc is moved toward the edge of the driver.

In some forms, the driving disc is held pressed in engagement with the driven member by a coil spring, and the clutching action is re-

leased by compressing the spring to relieve the pressure existing between the two transmission members. This is true of the form shown at Fig. 306, as the connection between the pedal to release the friction and the shifting member that compresses the spring are clearly shown. In order to provide a greater pressure than that afforded by the spring under conditions where the resistance is severe, an additional pedal is provided which is adapted to augment the pressure produced by the spring and thus obtain greater adhesion between the transmission parts. The driven disc, which is adapted to be moved laterally on a cross shaft, is faced with strawboard fiber which has a greater amount of adhesion with a cast iron driving member than any other material, and which is also enduring. Those who do not favor the friction type of transmission contend that it is very inefficient because there is considerable power loss due to slipping. While this is true of the extreme low speed and reverse position, the losses on the speed most used which is the range between the letters B and C in the illustration Fig. 307 is from 8 to 16 per cent. When on the highest speed position, or at B, there is but 8 per cent slip.

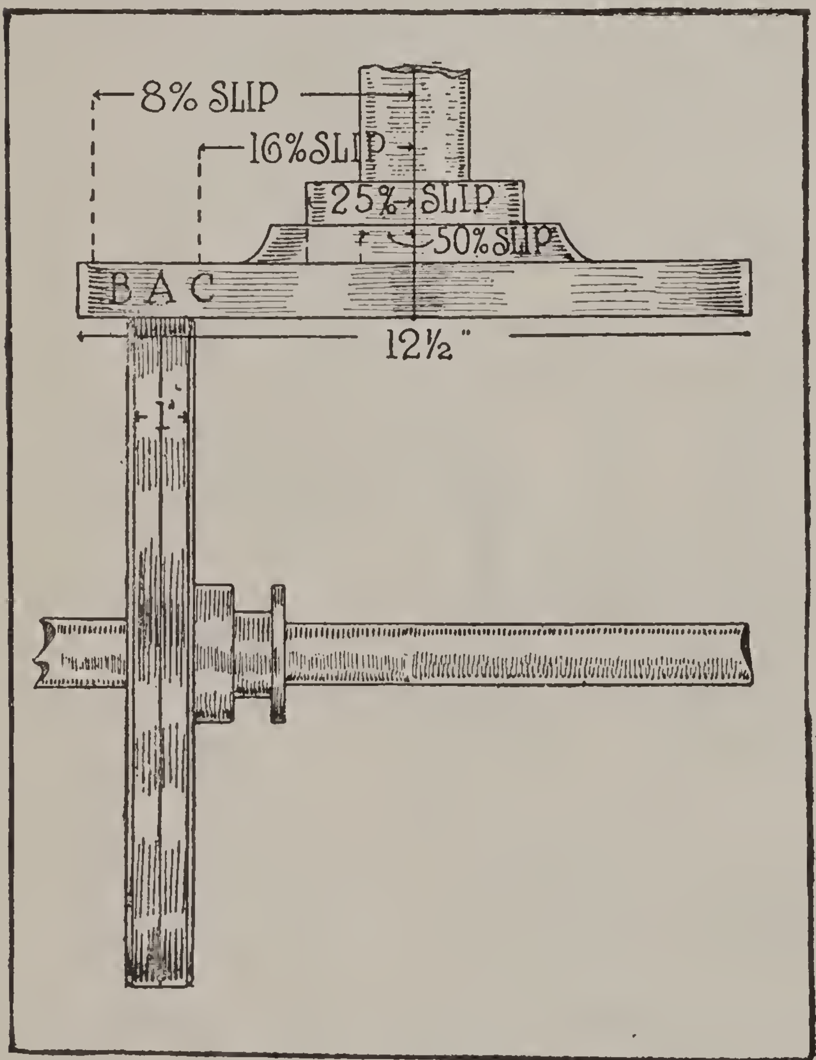


Fig. 307.—Diagram Illustrating Slip in Friction Transmission at Various Friction Wheel Positions.

A simple form of change-speed gearing in which two forward speeds are provided but no reverse which is used on the Morgan three-wheel cyclecar is shown at Fig. 308. The drive is by shaft from the engine located at the extreme front end of the vehicle to a bevel pinion that

is meshed with a bevel gear on a cross shaft. The gearing is encased. At either side of the case a sprocket is mounted that is adapted to turn freely on the cross shaft unless it is clutched to it by a sliding jaw clutch. One of the sprockets connects with a large sprocket on the rear hub, the other is joined to another sprocket of smaller diameter than the neighboring one. When the dog clutch is moved over as indicated in the illustration, the high-gear sprocket is clutched to the cross shaft, while the low-gear sprocket is free to revolve idly on that member. The clutches are attached to a common shifting rod that

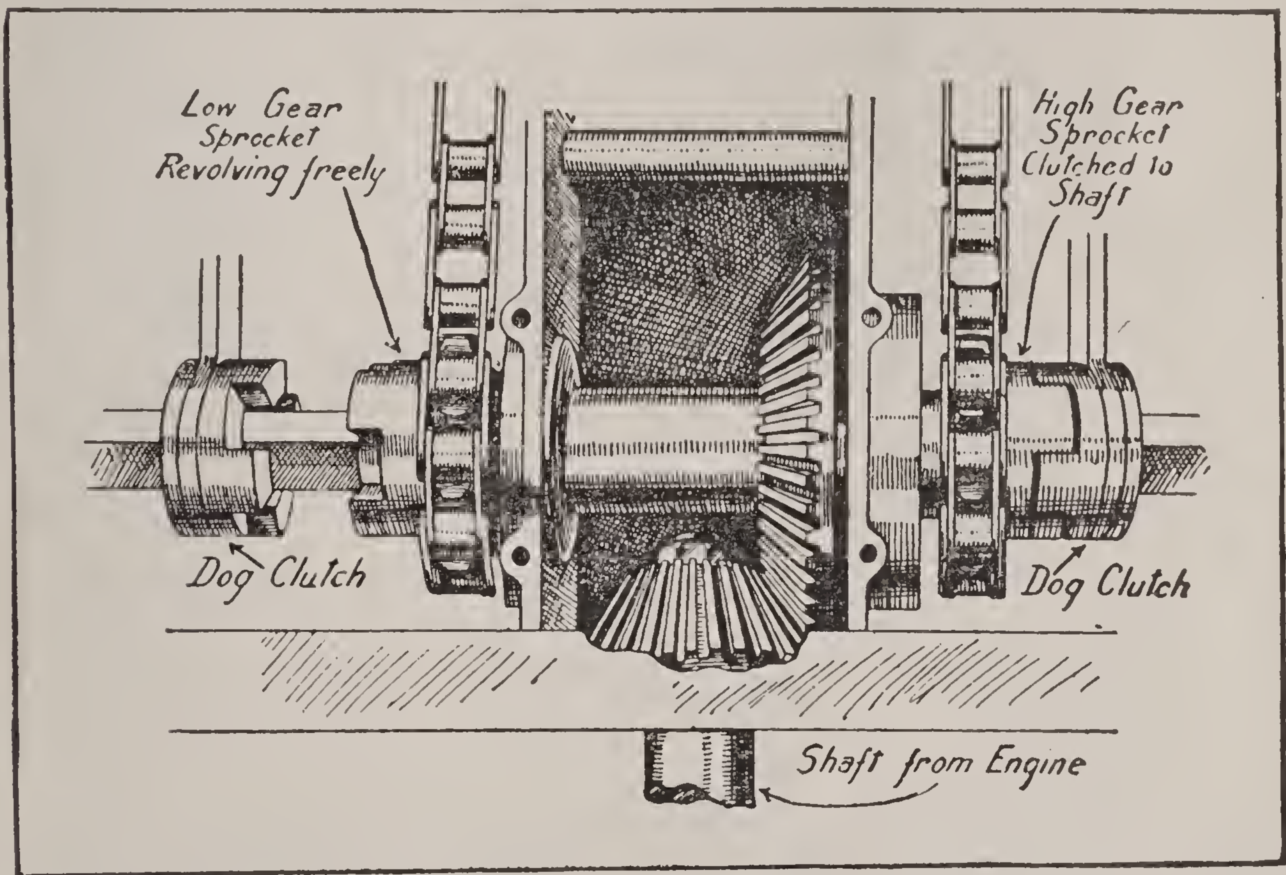


Fig. 308.—Positive Clutch Controlled Two Chain Change Speed Gearing of Morgan Cyclecar.

permits of three positions. One of these gives the high speed, an intermediate point is a neutral position in which neither sprocket is driven by the cross shaft, while the third is the low-speed position. It will be evident that only one sprocket will drive at a time. It is necessary to provide a master clutch of the friction type with this form of transmission because the speed-changing clutches will be much too harsh in action, and would take hold much too suddenly to be used alone.

The planetary form of gear which has been used to some extent in both motorcycles and automobiles has also been adapted to cycle-

car use. Its action is very similar to that of the simpler forms used in motorcycles previously described. There is one difference, however, and that is the cyclecar transmission of this type is provided with a reverse ratio in addition to the slow speed provided on motorcycles. The construction of a planetary gearset intended for shaft drive is shown at Fig. 309, while the method of construction followed when the transmission is attached to the cross shaft is clearly outlined at Fig. 310. In this case, the drive is by roller chain from the engine to a sprocket, to drive the transmission or change-speed gearing.

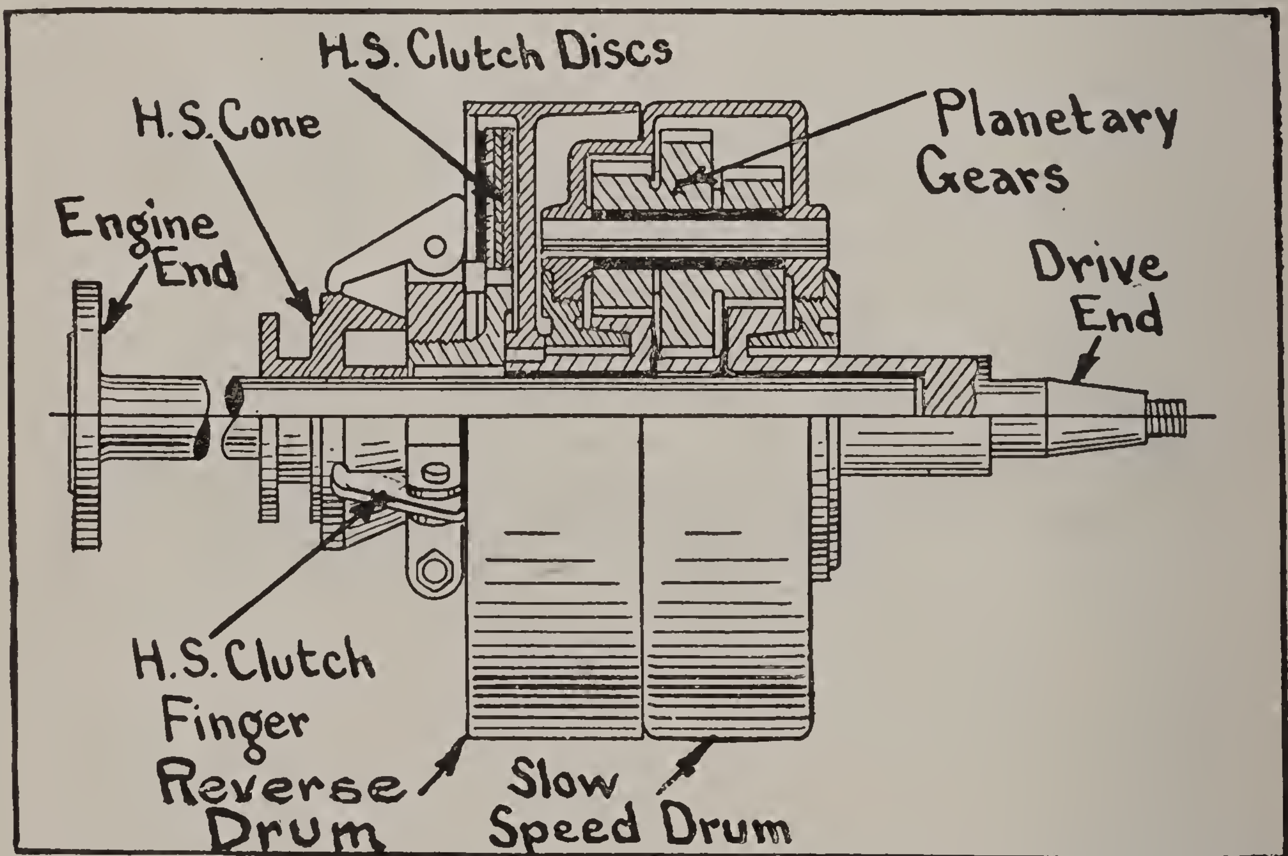


Fig. 309.—Part Sectional View of Two Speed and Reverse Planetary Gearing for Cyclecars and Light Cars.

This assembly is mounted on a hollow shaft or quill through which the cross shaft passes. The ends of the cross shaft are tapered to receive the usual V-belt pulleys or a roller chain sprocket at each end for the final drive to the rear wheels.

Power Transmission Methods.—The usual method of driving the true cyclecar is by the V-belts that have been previously described at length because used in motorcycle design. The V-belt may be used in two forms: the belt may be very long and extend practically the length of the cyclecar or it may be considerably shorter as is the case

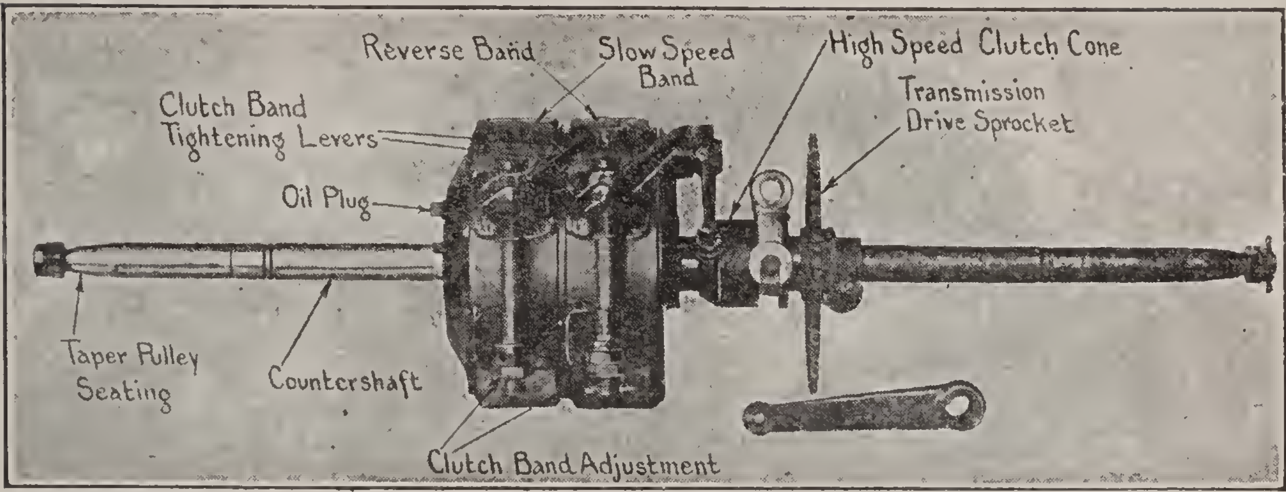


Fig. 310.—The Spacke Two Speed and Reverse Planetary Gearset Applied to Countershaft for Final Drive by V Belts.

in motorcycles. On the original simple cyclecar forms, the long belts were utilized because they permitted a certain degree of free engine action if the rear axle was moved forward so that belts were slackened. When it was desired to drive the vehicle, the entire axle is moved back until the belt tension is sufficient to grip the pulleys positively. This method of control, which is shown at Fig. 311, is not used very widely because it was found that the belts did not respond very kindly

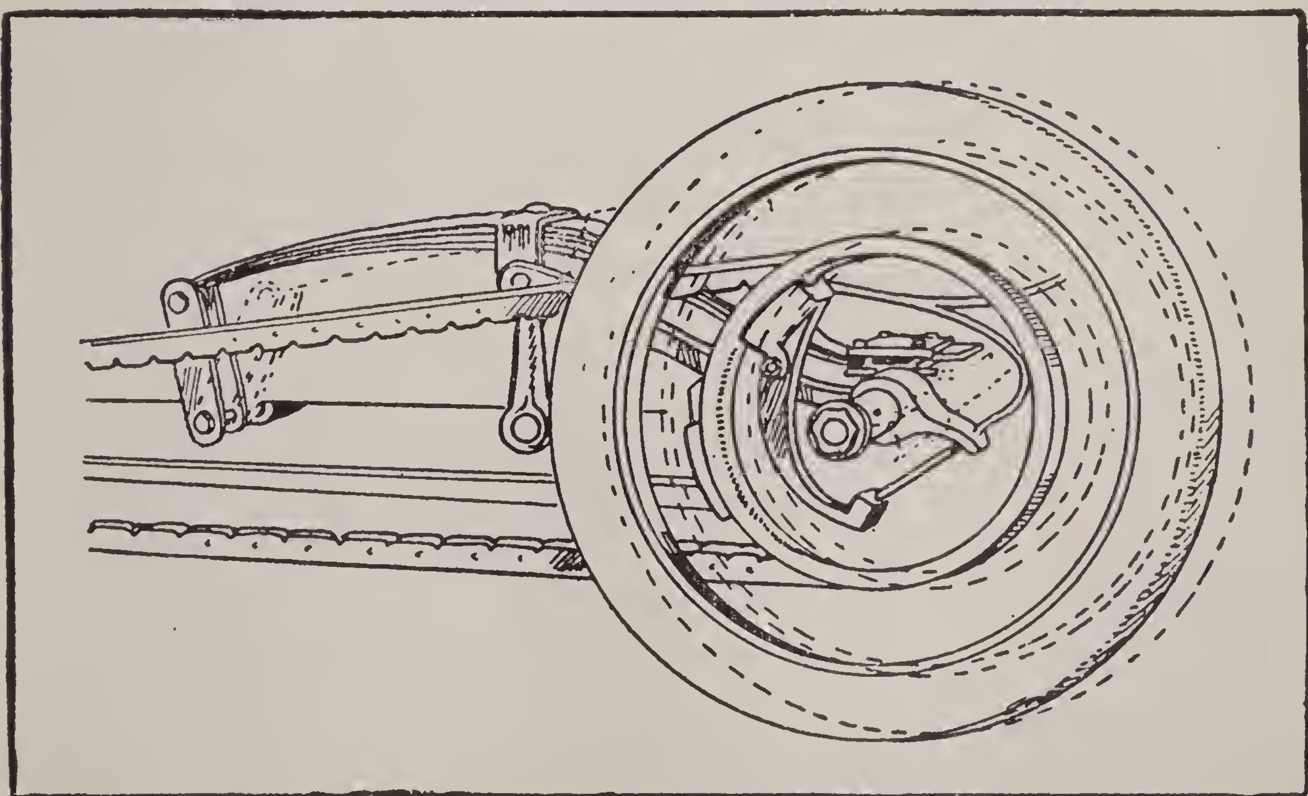


Fig. 311.—Diagram Showing Method of Obtaining Clutching Action With V Belt by Moving Rear Axle.

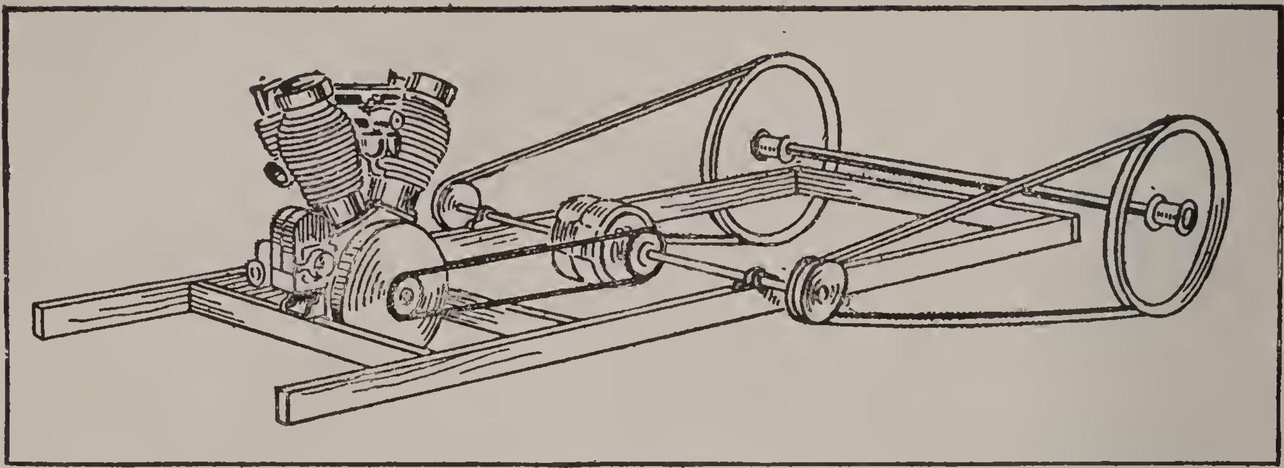


Fig. 312.—Diagram Showing Method of Using De Luxe Motor and Spacke Cyclecar Transmission With Final Drive by V Belts.

to the friction present between the small driving pulley and the belt whenever it was desired to obtain a free engine action. The approved method of transmission when a planetary transmission is used is shown at Fig. 312. In this, a Spacke two-cylinder motor is arranged in much the same manner as it is placed in a motorcycle, i. e., one cylinder is behind the other. The drive from the sprocket attached to the engine crankshaft is to the similar member secured to the planetary transmission such as shown at Fig. 310. The drive from the V-pulleys at the end of the cross shaft is to the larger members attached to the rear wheels, which in this case are not shown in the illustration. The movable rear axle used on the early forms of cyclecars had important advantages in that the vehicles provided with this method of transmission are the simplest types that can be devised.

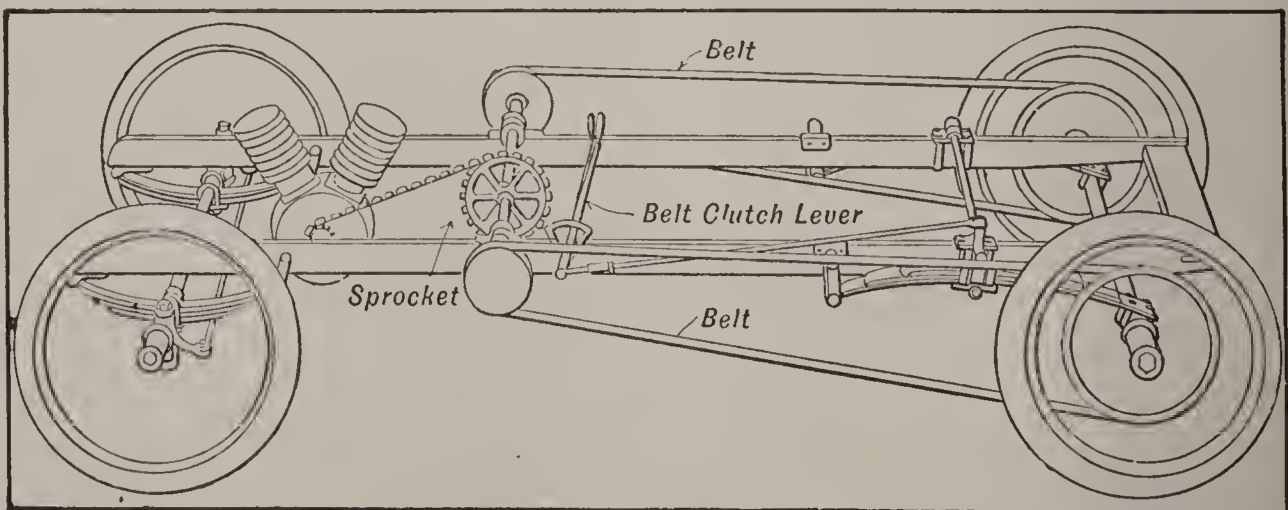


Fig. 313.—Chassis Plan of Simplest Form of Cyclecar, Showing Transmission System Involving Clutch Action by Movable Rear Axle.

It will be observed that the chassis construction outlined at Fig. 313 is a four-wheel motor vehicle reduced to its elementary form. The engine, which is an air-cooled motorcycle type having two cylinders set at an angle, is secured at the front end, where it will get ample cooling. The wire wheels are carried by miniature steering knuckles attached to a light tubular front axle. The spring suspension at the front end is by semi-elliptic leaf springs which combine the duties of a resilient support for the frame as well as distance or

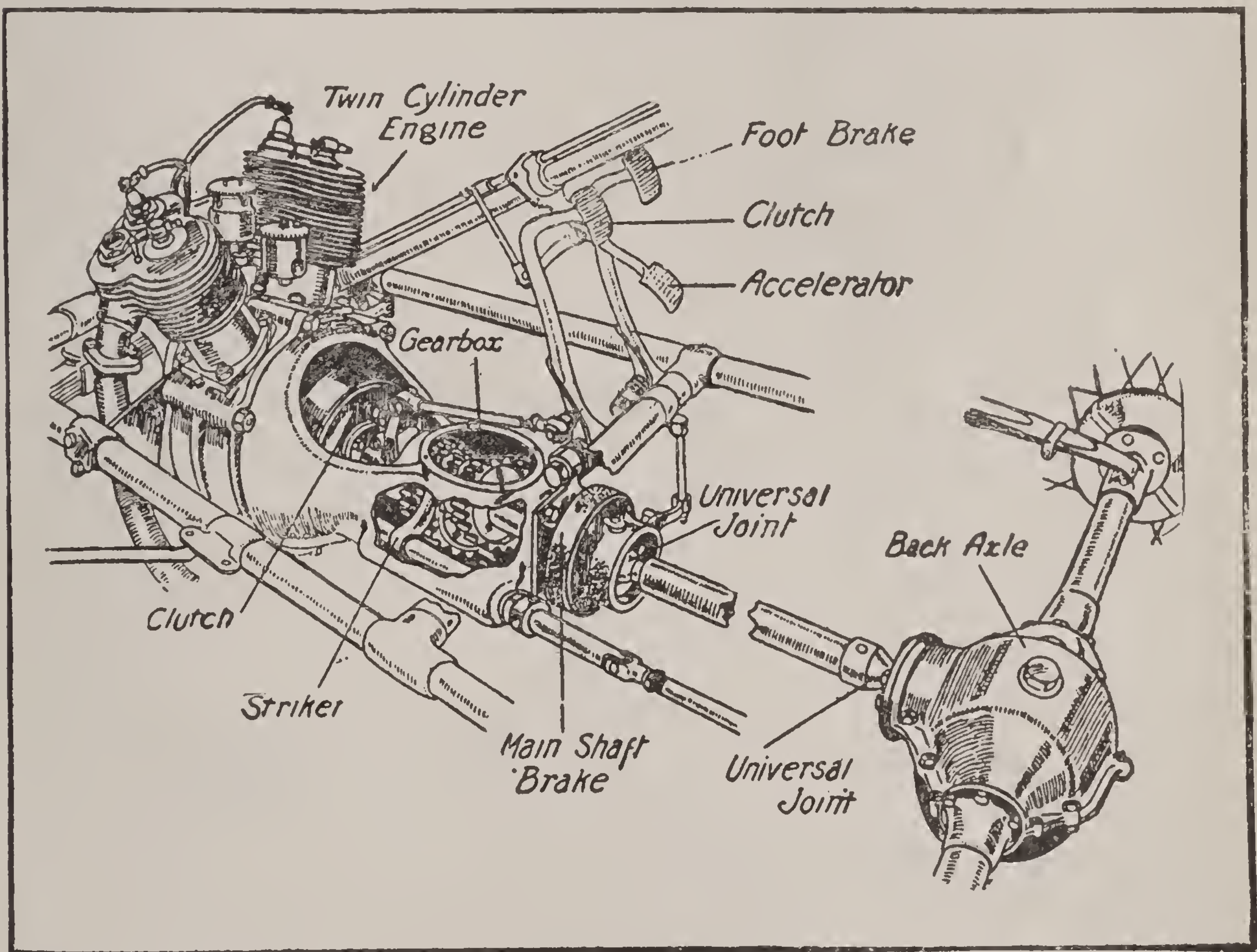


Fig. 314.—Change Speed and Power Transmission System of the Humberette (English) Light Car.

radius rods for the axle. The wood frame is extended to the rear, and in most cyclecars it is made of ash. The drive from the sprocket on the engine crankshaft is by a motorcycle roller chain to a larger sprocket on the countershaft. At each side of the countershaft V-belt pulleys are mounted which drive the rear wheels through leather belts. In the simple form shown the clutching action is obtained by sliding the axle back to tighten the driving belt and produce forward motion,

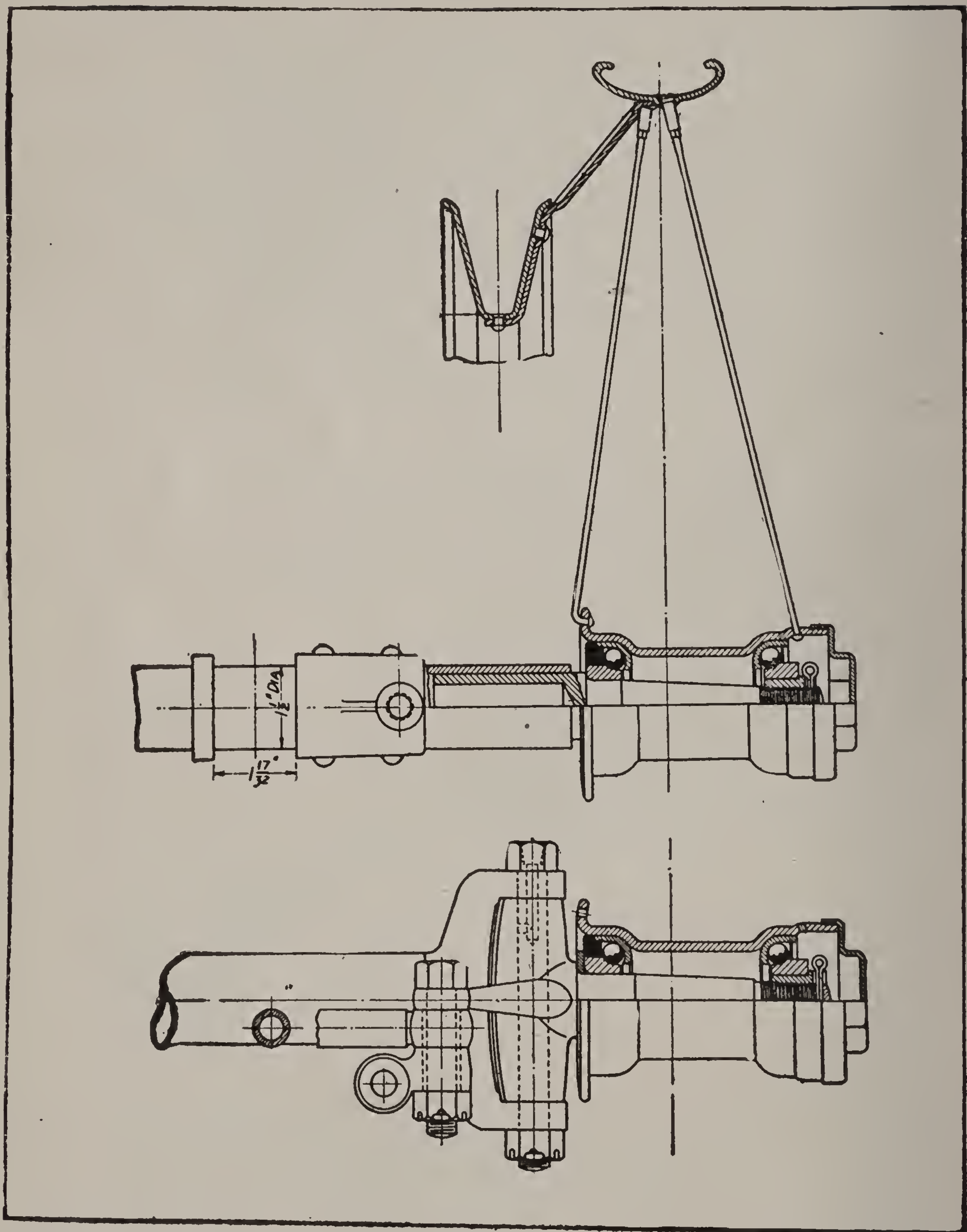


Fig. 315.—Front and Rear Axle Construction for Simple Type Cyclecar.

while it is pushed forward to loosen the belt and obtain a free engine action by the belt slipping over the pulleys.

In the cyclecars that follow automobile practice, one finds the same method of drive used as generally employed in the larger vehicles.

An example of the unit power plant and shaft drive of the Humberette (English) is shown at Fig. 314. The motor, which is a twin-cylinder air-cooled form, is made in a unit with the clutch and change-speed gearing. From the rear end of the change-speed gear, a propeller shaft extends, that is provided with a universal joint at each end that drives bevel gearing in the rear axle. Complete description of all these methods of drive will be found in the writer's work on automobiles previously mentioned.

The method of attaching the V-belt pulley to a motorcycle or cyclecar wheel is clearly outlined at Fig. 315. The wheel which is of the usual wire spoke form with the exception of employing heavier rim section, hubs and spokes than are generally used on bicycles, but of about the same strength as provided for motorcycles, revolves on a stationary spindle attached to a tube that forms the rear axle. The V-belt pulley, which is a steel member rolled to the proper shape, is attached to the rim by a series of arms riveted to the pulley and to the rim member.

Steering Arrangements.—There is some diversity of practice in the steering arrangements used on cyclecars. The first form evolved had the entire front axle movable around a fixed central point, though the later designs for the most part use a pivoted steering knuckle construction that is so generally applied in automobile construction. Two forms of steering gears are outlined at Fig. 316. That at A shows a rack and pinion reduction construction in which the rotary motion of a small pinion at the end of a steering post is transformed to a lateral movement of the rack with which it meshes. A drag link connected to this rack transmits its motion to the tie-bar connecting the two steering knuckles and the wheels may be set at the proper angle for steering with minimum effort. This is not true of the form where the entire front axle swings, because it is more difficult to move the wheels in soft sand or when the wheels are in ruts when the entire axle is moved than when the wheels are carried on spindles and the axle is fixed.

In order to simplify the construction, some designers have used cables passing around a drum at the end of a steering column to join the steering knuckle arms. The use of the drum provides a reduction in effort when steering the vehicle on account of the leverage obtained

when the cables are wound close to the center of the steering column. With this system, it is essential that tension springs be provided to keep the cables taut at all times. When the entire front axle is swung around the cable construction is generally followed, though when the wheels are mounted on movable steering spindles secured to a fixed axle the Ackermann or direct rod system is considered much more positive and satisfactory. The cables will wear in time, especially

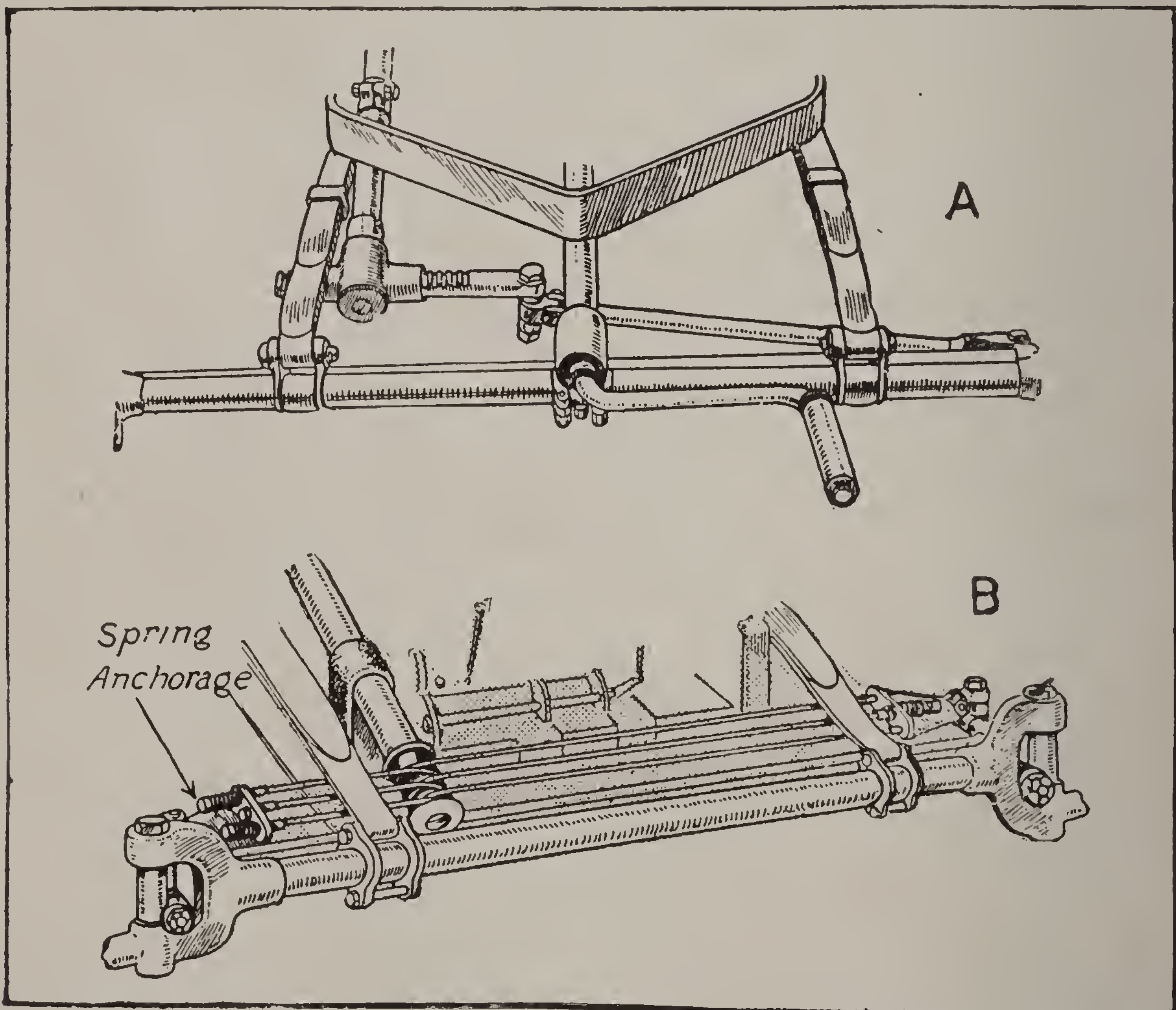


Fig. 316.—Methods of Steering Cyclecars. A—By Rack and Pinion Reduction Gear. B—By Wire Cables and Drum.

if they rub against any part of the frame structure. When rods are used these can be proportioned to take the strain and there is no depreciation of the steering system that is apt to result in derangement of this important directive function.

Methods of Springing.—Careful attention must be paid to proper springing of a light vehicle, such as a cyclecar, and it is imperative that the supporting members and their arrangement should be care-

fully selected in order that they may be resilient and yet strong. While the supporting systems followed in automobile practice have been adhered to very closely by cyclecar designers a number of distinctive forms in which the springs perform the dual function of axle and springs have been evolved. The simpler types of springs are the most common, namely, the semi-elliptic and the quarter elliptic forms, though several instances where full elliptic springs are used may be noted. The distinctive spring suspension of the Falcon cyclecar is shown at Fig. 317. In this, the frame is supported by three points,

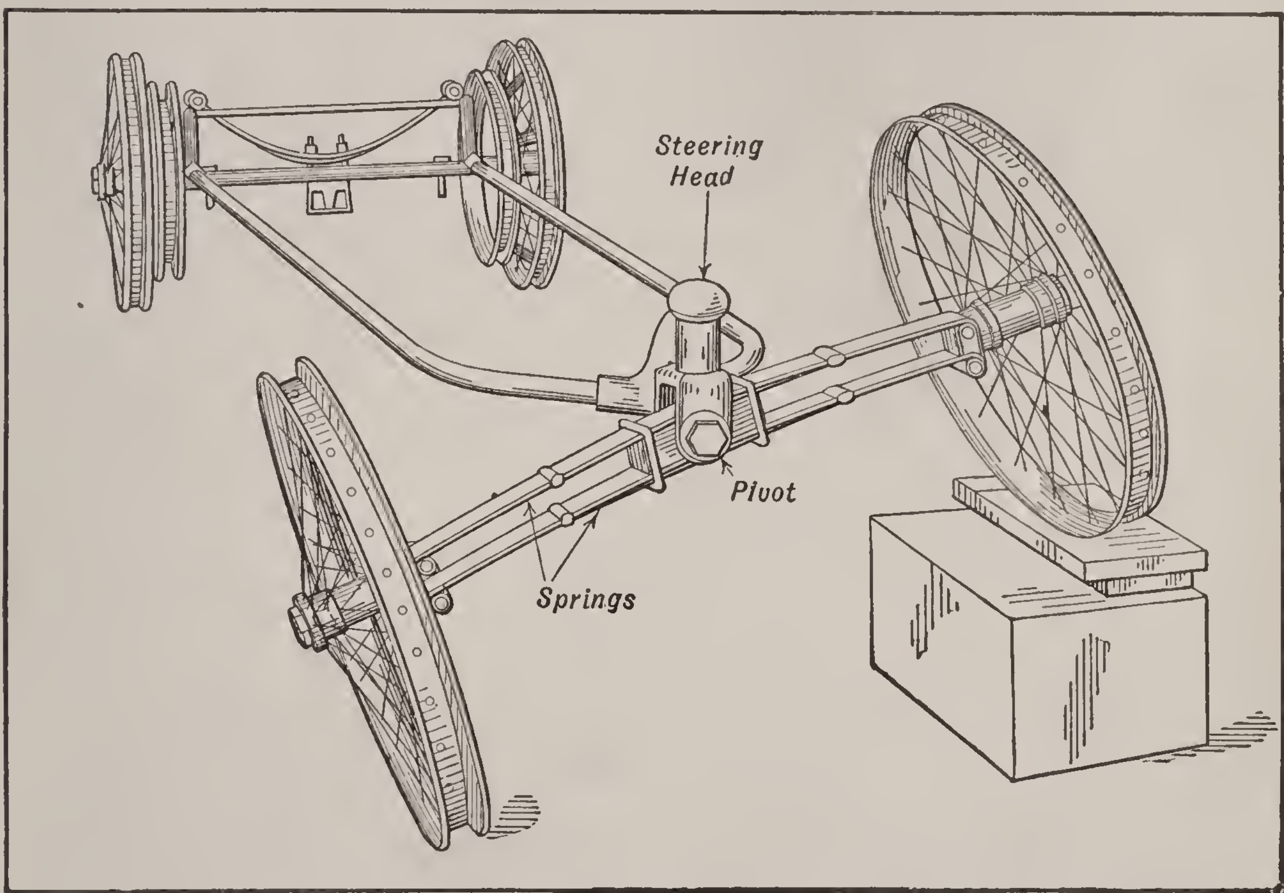


Fig. 317.—Diagram Showing Flexibility of the Falcon Cyclecar Chassis and Three Point Support System.

one at the front and two at the rear. The front-spring construction is such that these members replace the usual form of axle, inasmuch as they are attached directly to members on which the wheels are mounted. The springs are supported by a block at their center point which is pivoted to a steering head that permits the axle to be swung around for steering. The supporting pivot provides a very effective three-point support because one wheel may be considerably higher than the other without displacing the frame. This method of com-

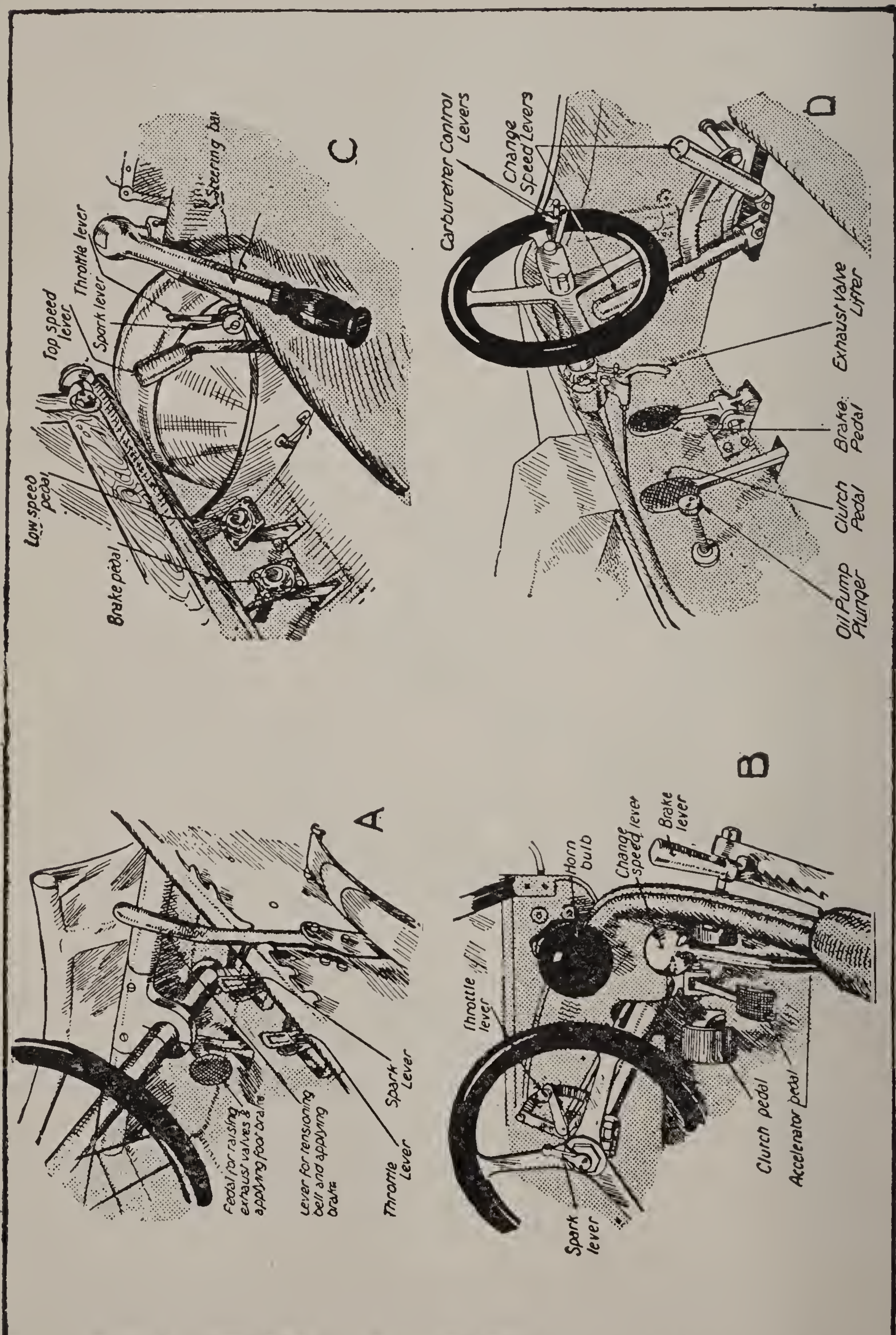


Fig. 318.—Defining Control Methods of Typical Foreign Cyclecars.

bining the spring and axle functions is also followed on the Imp cyclecar, though modified to some extent.

Cyclecar Control Methods.—Cyclecar control methods differ widely, and depend entirely on the system of power transmission employed. For example, the control group shown at Fig. 318, A, is adapted to vehicles of the Bedelia type. The engine speed is varied by the usual spark and throttle-control levers which in this case are secured to the side of the frame. A pedal is provided for raising the exhaust valves and applying the foot brake. A long side lever is utilized to move the axle back and forth to obtain either the free engine or clutch action and to apply the brakes. When the axle is moved back, the belt tension is increased and the engine drives the wheels. When the axle is moved forward, a free engine action is obtained up to a certain point beyond which a continued movement of the side lever will apply brakes to the V-groove pulleys on the rear wheel.

If this method is contrasted with the complete control system, shown at B, it will be evident that in the latter the general arrangement is much the same as prevails in automobile practice. The engine speeds are controlled by the usual spark and throttle levers which are mounted on the steering column. Three pedals are provided: one to control the clutch, one to govern the throttle of the carburetor, and the third to apply a foot brake. The lever inside of the body is used in changing speeds while that on the outside applies the emergency brake. The control system of the Auto Carrier three-wheel cyclecar, previously described, is shown at C. Steering in this case is by a steering bar instead of the usual hand wheel. The spark and throttle levers are conveniently mounted at the side of the body, and regulate the magneto contact breaker and the throttle slide through Bowden wire mechanism. Owing to the peculiar form of transmission employed, one handle is used for the high speed and a pedal is provided for the low speed. The other pedal applies the brake. Another form following current automobile practice very closely is shown at D. This is practically the same in general arrangement as the form shown at B, except that two additional controls are provided. One of these is an exhaust valve lifter, the other is a foot-operated plunger arrangement intended to work the oil pump.

The methods of starting the engine and controlling its speed that are given in the following chapter will apply just as well to the power plants used in cyclecars as to those designed for motorcycle propulsion. The general hints for maintenance and repair of power plant and transmission systems, also location of troubles and lubrication advice can be applied to advantage by the cyclecarist, as well as the motorcyclist. A careful study of the chapters on power plant operation, carburetion and ignition will prove just as valuable to the person interested in cyclecars only as to the motorcyclist because the principles that obtain and on which the action of the various parts of the power plant group are based apply to all forms of gasoline engines regardless of where used.

CHAPTER VIII.

MOTORCYCLE MAINTENANCE, OPERATION AND REPAIR

Motorcycle Equipment—Lighting Systems—Alarms, Tools and Supplies—Directions for Starting Motor—Instructions for Operating Motorcycle—Advice on Lubrication—Motorcycle Troubles—Classification of Engine Defects—Testing Ignition Systems—Common Faults in Carburetion Systems—Causes of Lost Compression—Causes of Irregular Motor Operation—Conditions Producing Overheating—Causes of Noisy Operation—Valve Removal and Grinding—Removing Carbon Deposits—Instructions for Running De Luxe Motors—Defects in Power Transmission Elements—Testing for Chain Alinement—How to Adjust Chains—Slipping Belt Drive—Care of Leather Belts—Care of Wheels—Common Defects in Clutches—Derangements in Change Speed Gearing—Adjustment of Brakes—Repairing Inner Tube Punctures—Outer Casing Repairs—Advice to Purchasers of Second Hand Motorcycles.

Motorcycle Equipment.—Of the innumerable accessories that have been devised for use of the motorcyclist, either for his personal benefit or to be used in connection with the machine, fully three-quarters are unnecessary, and can be easily dispensed with. It is not the writer's purpose to describe all of the various articles of equipment because the opinions of the various riders differ as to what should be considered necessary and what may be just as well omitted. Assuming that the rider has received a bare motorcycle without any auxiliary fittings whatever, it will be well to enumerate briefly some of the accessories that are really necessary in order to insure safety and comply with the law.

The first thing needed is adequate lighting equipment, and in most states a tail light is required as well as a head light. The next fitting prescribed by law is some form of signal or alarm by which the motorcyclist may notify other users of the highway of his approach. There is always a certain number of tools and spare parts that can be

carried to advantage and that are not furnished with the machine. The equipment of a motorcycle does not include a speedometer unless one purchases a special model that is sufficiently expensive to have the cost of the accessories included in the purchase price.

The speedometer, which indicates the speed attained, and which also includes a mileage recorder, is a very necessary fitting. One is not only able to keep the speed in accordance with the legal requirements, but a reliable speed indicating device forms a good check on

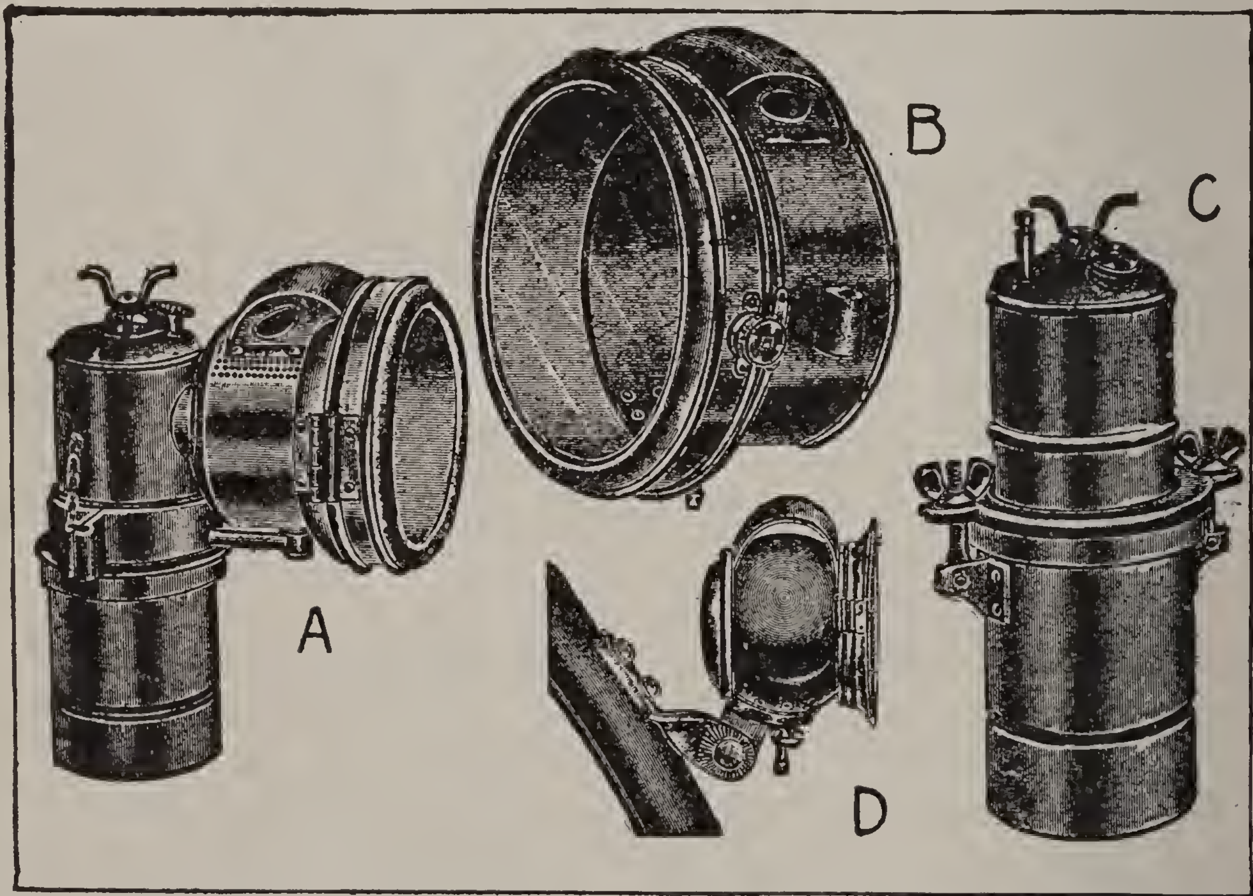


Fig. 319.—Forms of Gas Lamps and Generators Used in Motorcycle Lighting Systems.

motor action and when to oil. The mileage recorder enables the rider to keep track of the service given by tires or other parts, and the amount of gasoline and oil consumed in covering a given mileage. The cost of the average motorcycle speedometer will be exceeded by a substantial margin if fines are paid for just one violation of the speed law, so it is much better to insure against arrest and obtain all the other advantages by investing in a speedometer than it is to pay more than the cost of one of the devices to swell the bank account of some rural constable. Another article of equipment is a watch and

holder designed for attachment to the handle bars. Weed chains should be provided for the tires to minimize skidding; they are light and easily carried as they occupy but little space when not in use.

Lighting Systems.—The kerosene burning lamps used on the bicycle do not provide sufficient illumination for the motorcycle, on account of the greater speed of the power-propelled form. The various forms of lamps that are widely employed utilize acetylene gas as fuel and throw a brilliant light which will illuminate the road for several hundred feet ahead of the motorcycle. The lamp shown

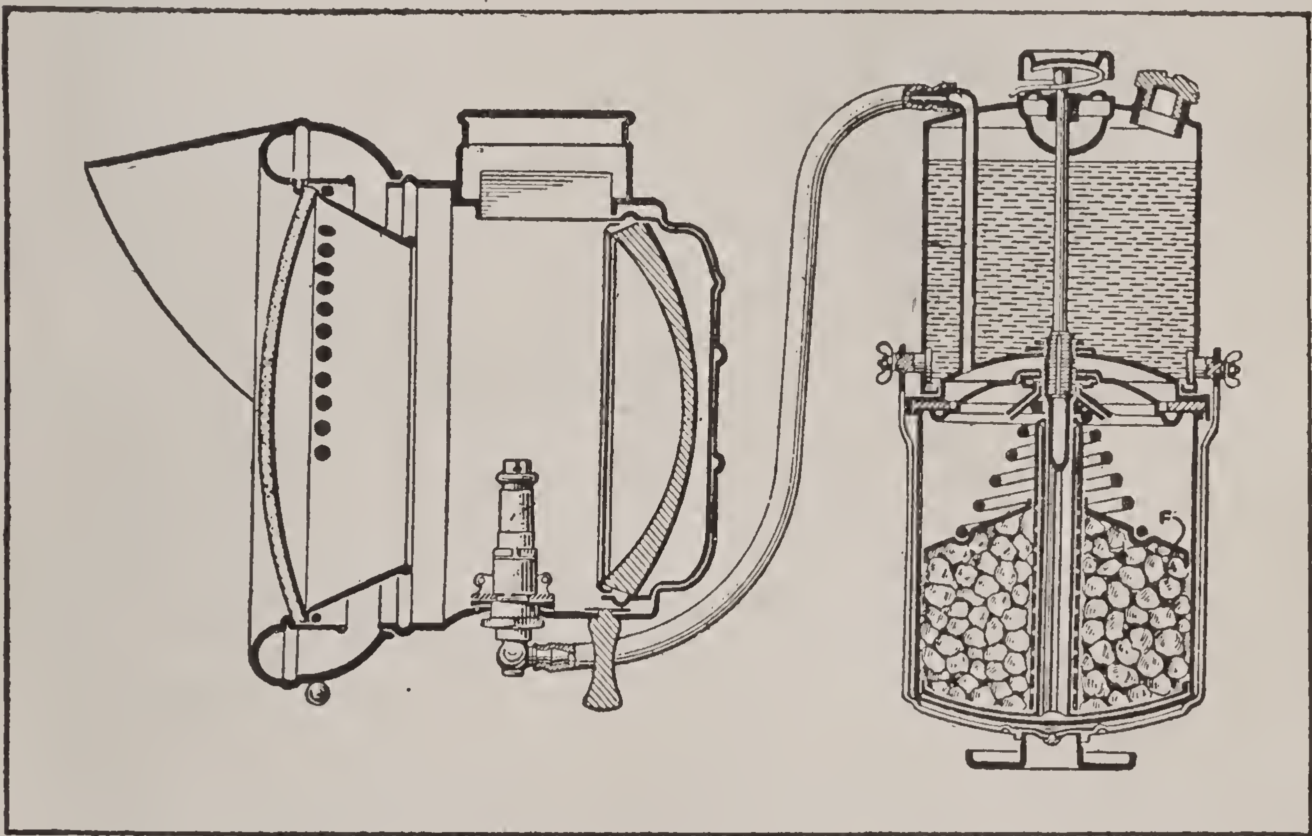


Fig. 320.—Diagram Showing Construction of Gas Lamp and Acetylene Generator.

at Fig. 319, A, is combined with the gas generator, which is a simple device for producing acetylene gas by the chemical action of water on calcium carbide. While the generator has been widely used, it is being superseded in many cases by the Prestolite tank in which the gas is stored under pressure, and from which it may be taken as needed by a simple operation of the tank valve. The searchlight shown at B is a separate type which can be used in connection with either the separate generator shown at C or the gas tank with which all are familiar. A small gas burning lamp designed for attachment to the rear mud guard is shown at D.

The method of operation of a generator may be clearly understood by referring to Fig. 320. As will be apparent, the device consists of two parts, an upper chamber to hold water and a lower portion divided in two compartments, one of which holds carbide while the other provides space for the gas to collect in. The carbide in the lower chamber surrounds a central tube in which measured quantities of water from the upper chamber are allowed to drip. The water is controlled by a needle valve, and the more water admitted the more energetic the liberation of gas becomes. The gas passes through a cooling chamber at the bottom of the upper portion that holds the water, and from there it passes to the burner in the lamp, through a length of rubber hose. After the carbide has been used up, which is evidenced when it has turned from the state of crystals or lumps to dust, the lower portion of the generator must be removed and thoroughly cleared out and fresh carbide inserted before one will obtain any more gas.

The combined electric starting and lighting system of the Indian motorcycle has been previously described at length, but other systems of electric lighting have been offered that are adapted to be fitted to motorcycles of any pattern. The simplest method of obtaining electric lights is to use a battery of some form carried by a simple container, which in some cases may be attached to the lamp. Either dry cells or storage batteries may be used. If much night riding is to be done, the storage battery will be the most practical form, though dry-cell arrangements will give very good light if properly installed.

As previously pointed out, any chemical current producer becomes depleted as it is used, so a number of small generators have been evolved to furnish the current for lighting. One of these, shown at Fig. 321, is driven by a friction wheel that bears against the front tire, and charges a storage battery which, in turn, delivers current to the searchlight. The object of using storage battery, in connection with mechanical generator, is to insure the delivery of a uniform current to the lamp filament. As the electricity generated by the simple form of dynamo or magneto will vary in quantity as the speed the armature turns varies, when the motorcycle is driven fast, excess current might be generated that would burn out the lamp

filament. When running slow, the current is weak and the illumination proportionately feeble. If instead of delivering current directly to the lamp, the dynamo delivered its energy to a storage battery, that member serves as a reservoir and an equalizer, and delivers current of constant value to the lamp. Some attachments are offered wherein the dynamo is driven from the motor by small wire spring belts or round leather forms. These have a defect, in that it is difficult to obtain reliable service from the belts which are constantly breaking. The drive from the tire is not perfect by any means, as

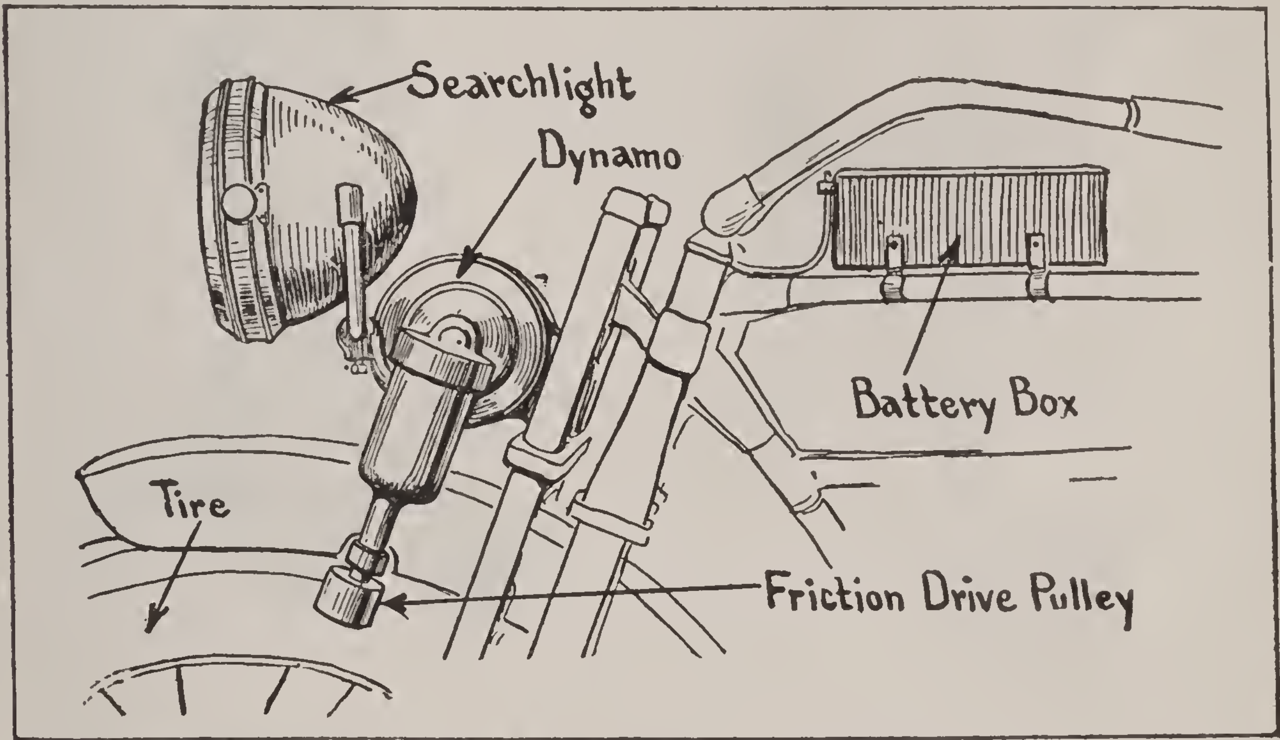


Fig. 321.—Showing Installation of Friction Drive Dynamo to Furnish Current for Electric Lamps.

the friction drive pulley of the magneto will produce a certain amount of depreciation at the point of contact on the tire, and may slip when the tire becomes coated with water or mud. If a mechanical generator of electricity is to be included in the motor cycle equipment this should be preferably built in as a part of the machine, and be driven by positive gearing, as is the case on the Indian motorcycle.

Alarms, Tools and Supplies.—On machines that are provided with electric lighting, it is not difficult to use electric alarms in the form of vibrating diaphragm horns which are set in action by a simple pressure on a push button. When a machine is not provided with batteries and a loud alarm is desired, a mechanical horn such as shown

at Fig. 322, A, will produce a louder tone than the usual electric buzzer arrangement. This is a diaphragm form, and is similar to the type that is so widely used on automobiles. A downward pressure on the plunger extending from the back of the horn casing sets the train of gears in motion which, in turn, actuate the diaphragm at a rapid rate. The simpler forms of bulb operated horns such as shown at B and C are also adapted for the motorcycle, but these do not provide

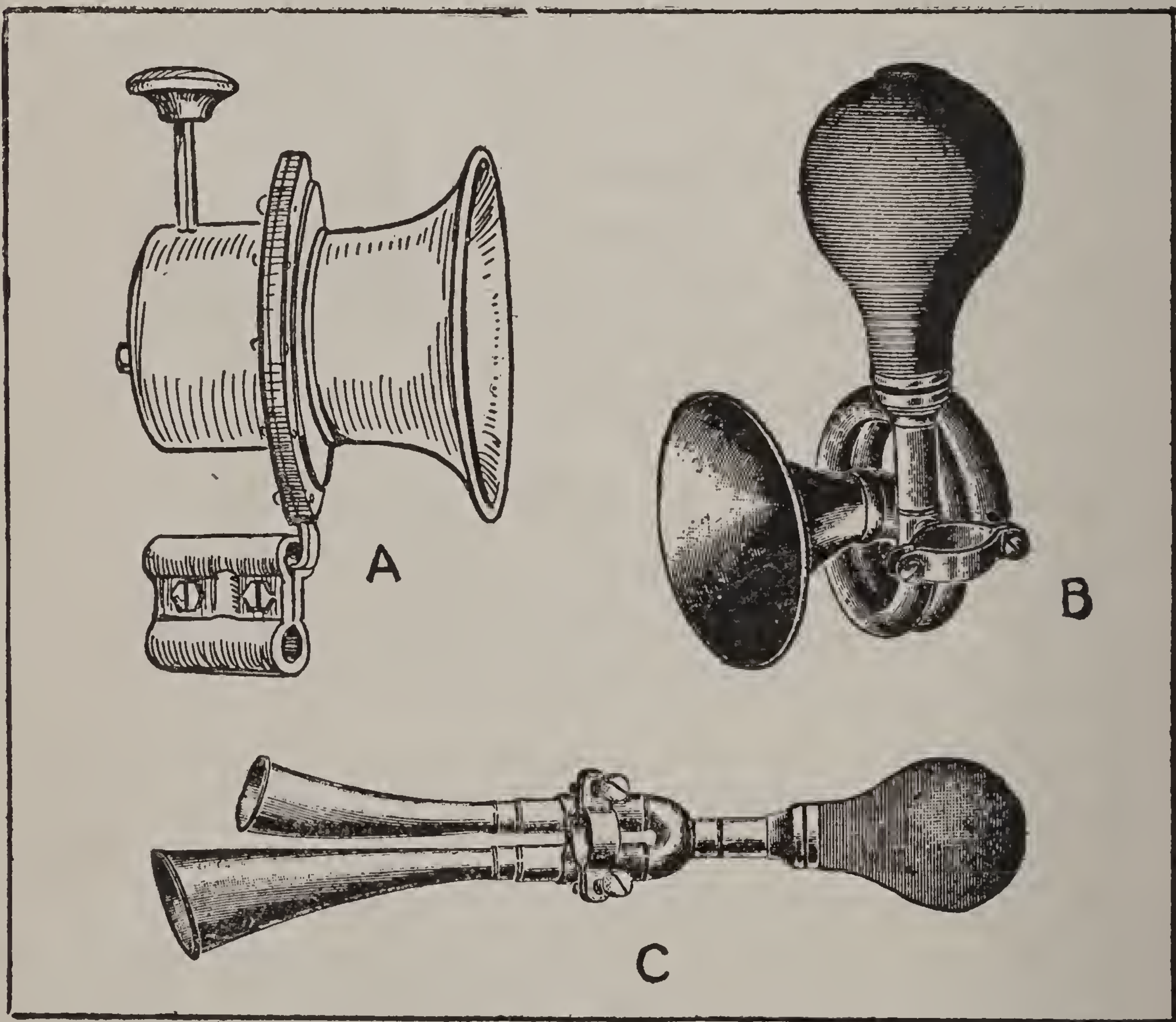


Fig. 322.—Popular Forms of Motorcycle Alarm Signals.

the best alarm when touring, inasmuch as their note does not have a very great carrying power. The shriek of the mechanical horn can be heard for many hundred feet.

It is difficult to outline the tools that should be provided because so much depends upon the character of the machine and its equipment. Most motorcycle manufacturers provide the special tools that

are needed to get at any adjustments or nuts and bolts that would not be accessible with the ordinary tools obtained in the open market, so it will not be necessary to describe the special socket wrenches or spanners that fit only certain makes of machines. The main item of the average tool kit is a monkey wrench of special, light, thin form that still has a large enough opening to take the largest nut on the machine. For instance, if the inlet-valve cage screws into the cylinder, or if valve chamber caps are used the wrench should be large enough to move either of those members, which are usually the largest of the parts that must be handled by the wrench. A small size wrench of the bicycle type is also convenient and does not occupy much space. Two screw drivers should be provided, one small one with a blade that will permit removal of the smallest screws on the machine (such as those on the magneto) and one a little larger in size, preferably short and stubby with a strong blade for handling the other members that are screwed in tighter, and which could not be very well removed with a light screw driver.

A pair of combination pliers are usually part of the equipment, but if these are not provided by the maker the rider should see that they are included in the tool outfit. The best all around form for motorcycle use is that which is provided with a joint of such form that the opening between the jaws may be varied. The jaws are provided with a flat portion at the extreme end and below this part, which is used for gripping flat stock, a semi-circular, serrated opening is provided in each jaw for gripping pipe or round objects. The lower portion of the jaws near the hinge are usually sharpened to a cutting edge and move over each other with a shearing action. This portion serves as a wire cutter. One or two small files are also desirable, as many occasions arise where they will prove useful. Other tools should be provided depending upon the transmission employed. If the V-belt is used, a belt punch or awl as well as several spare connectors may be included. If drive is by chain a chain tool for removing the rivet from the links, and a number of spare connecting links are necessary.

Among the spare parts that may be carried to advantage may be mentioned a small spool of copper wire about No. 16 gauge, a length of high tension cable, and a number of assorted bolts, split pins, nuts and washers that conform to those used on the machines. If a single

cylinder engine is employed as a power plant two spare spark plugs should be carried, while if it is a twin cylinder, three extra spark plugs should be included. To insure against breakdowns when away from the source of supplies, a few spare magneto parts such as the high tension carbon brush holder, a platinum pointed contact screw and a contact breaker bell crank will be found of advantage.

A roll of tire or insulating tape, and a complete tire repair outfit should figure in the equipment. The average outfit for inner tube restoration consists of a piece of emery cloth, a tube of cement, and some patches of assorted sizes. Patches may be obtained that do not require any cement as it is already incorporated with them, and a couple of these may be provided for an emergency where the regular cement would not work properly. Small tire irons to remove the casing from the rim and an air pump, as well as a number of spare valve insides, complete the outfit for repairing the inner tube. In case of a blow out, or a serious cut in the outer casing, it will be well to have an inside blow out patch and a tire gaiter handy. The inside patch is a piece of heavy canvas, 5 or 6 inches long and wide enough to conform to the curved interior portion of the tire completely when doubled over. The outer sleeve is made of leather or rubber and fabric, and is provided with a lacing by which it may be tightly drawn in place around the injured portion of the casing. If going on a tour of any magnitude, a complete inlet and exhaust valve assembly and several extra inner tubes will complete the kit.

The problem of carrying tools and supplies is not an easy one to solve on a motorcycle, though many very practical bags and carrying cases have been designed that will fit the top of the luggage carrier, or that are adapted to be carried one on either side of that member. These provide room for considerable material and enough equipment for a trip of some magnitude may be easily stowed away. The bag shown at A, Fig. 323, is intended for attachment to the side of the luggage carrier, and not only provides a large amount of storage space inside but has a smaller tool bag attached as well as a pocket to carry the oil can. The form at B is intended to be carried on top of the luggage carrier and is considerably larger than that designed for attachment to the side. The bag shown at C is also intended for the top of the luggage carrier, and when flanked on either side with a bag

of the form shown at A much storage space is available. Where machines are driven by belt, if one undertakes a long tour and the belt has seen considerable service, it may be well to carry a spare member in a special casing such as shown at D. The interior of this case is divided into two concentric compartments, the outer one serving for the belt, the inner one to carry the spare inner tube. If a side car is fitted, an opportunity for carrying considerable luggage

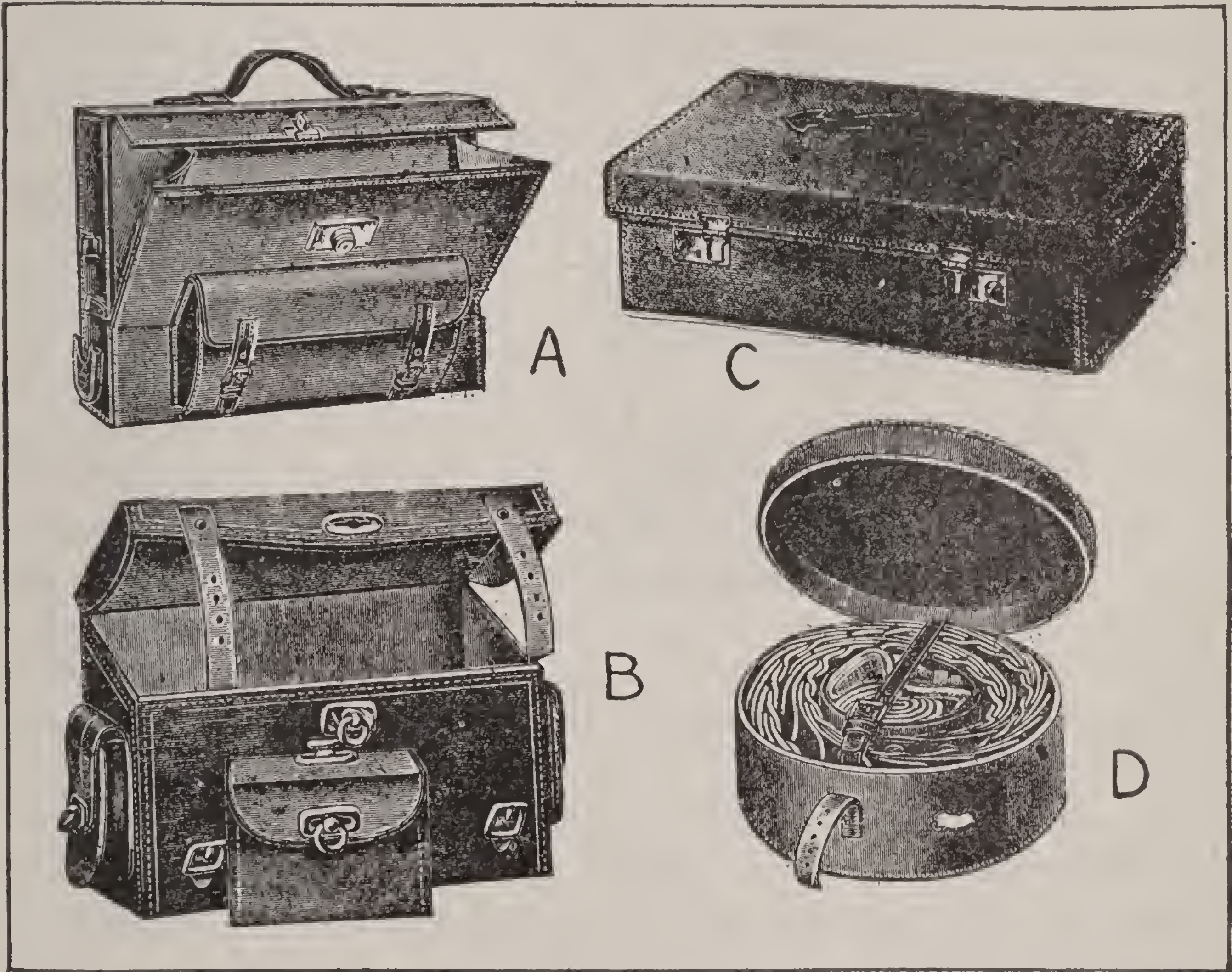


Fig. 323.—Examples of Cases Adapted for Carrying Tools or Supplies on Motorcycles.

may be taken advantage of by fitting a luggage carrier or rack, as shown at Fig. 324, to the back of the side car body.

Directions for Starting Motor.—Assuming that the rider has just received a machine, and that it has come crated, and also that he is not familiar with motorcycle operation, we may give the following general instructions: After the machine has been uncrated, and the handle bars, saddle and pedals attached in their proper places, the

first step is to see that the tanks are filled with gasoline and oil. As a rule, the filler caps are very plainly marked to indicate the purpose of the container to which they are fitted. In filling the tank with fuel, filter the gasoline by passing through a chamois skin which insures positive removal of all dirt and water. Be sure to fill the oil tank with the proper grade of lubricant, which must be a good air-cooled engine cylinder oil, and preferably of the brand recommended by the maker of the machine. Before attempting to start the motor, become familiar with the various parts of the controlling apparatus. In most American machines the gas supply is regulated by one of the movable grips on the handle bar, and which one it is can be easily ascertained by moving both of them in turn and seeing which operates on the throttle lever at the top of the carburetor. In some machines, the grip is turned in one direction to close the throttle which would be just the same as that to open the throttle in other motorcycles. The proper mode of procedure can only be determined by experiment. The grip on the other handle bar is used for advancing the timer or contact breaker of the magneto when turned in one direction and for raising the exhaust valves if turned to the other extreme position. In some motorcycles, the exhaust valves are raised by a special lever carried by the handle bars. The clutch of most motorcycles is operated by a hand lever at the side of the tank, and in some machines a smaller lever will be mounted at the side of the tank that is connected directly with the contact breaker of the magneto. When a two-speed gear of the planetary type is used, a single-control lever usually serves to control both high and low speeds, and this member corresponds to the usual free engine clutch actuator. When an individual or shifting clutch, two-speed gear is used, the master or friction clutch is often

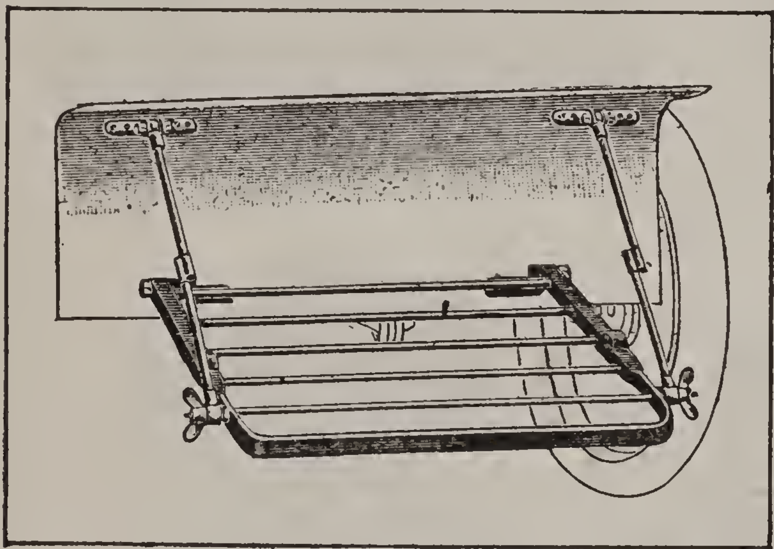


Fig. 324.—Application of Luggage Carrier at Rear of Side Car Body.

shifted by a foot lever, while the speed changing is effected by a very small lever carried on the upper frame tube.

The first thing to do is to learn to control the motor. To do this, raise the rear wheel of the machine from the floor by the stand provided for that purpose, open the valves in the gasoline line so the fuel will flow to the carburetor and supply a couple of pumpfuls of oil to the engine base. If a sight feed device is provided, this should be set to feed about eight drops per minute. Prime the carburetor by pressing the priming pin and holding that member down until gasoline flows from the bottom of the device. This shows that the spray nozzle has overflowed which indicates that it is clear of dirt. Set the spark about half way advanced, open the throttle slightly, and raise the exhaust valves by whatever means are provided for that purpose. Pedal briskly and turn the motor over at a fair rate of speed, and then drop the exhaust valves and the motor should start. After the motor has been started, become familiar with the action of the spark and throttle levers or control grips by moving them back and forth, and noting the effect of the various positions on the behavior of the engine. Do not run the engine unnecessarily fast when on the stand.

Instructions for Operating Motorcycle.—After having learned to manipulate the motor and control its speed on the stand, the motor may be started and allowed to run slowly, and the high-speed or free-engine clutch lever may be set in the free engine position. This may be clearly noted by pressing on the brake pedal with the engine in motion. If the rear wheel stops rotating without affecting the engine speed, it indicates that the clutch is free and functioning properly. If applying the brakes stops the motor as well as the rear wheel, it shows that the clutch is not properly released, which may mean that the lever is not in the proper position or that there is some defective condition in the clutch itself. The machine is then dropped off of the stand with the clutch lever in the off position, and, after the rider has mounted, the engine may be speeded up and the clutch lever moved gradually until the motorcycle acquires a certain momentum, after which the clutch may be engaged positively.

If the machine is a two-speed form, the start may be made on the high speed without any trouble, as the friction clutch will provide

gradual application of power if it is controlled properly. When starting on a hill or in sand, it will be well to start on the low gear and throw into the high only when the top of the hill is reached, or road conditions become more favorable. Do not slip a clutch of any type unnecessarily, because this will produce wear of the friction surfaces. In operating two-speed gears of the shifting clutch type or of the sliding gear pattern, always be sure that the master clutch is completely released before endeavoring to shift gears. When shifting from high speed to lower speed, always slow down the engine or wait until the speed of the motorcycle drops to the point that will correspond to the gear ratio obtained by the reduction gearing. In changing from the low to the high gear, accelerate the engine slightly to speed up the machine before the shift is made. Complete instructions for operating the engine, and proper manipulation of spark and throttle levers, as well as starting by hand crank or foot starter, are appended.

If one attempts to set an engine in motion by means of a hand crank with the spark lever advanced so an early spark is obtained, the motor may "kick back," and this reversal of motion, which is due to premature combustion, may sprain the wrist. It will be well to open the throttle or gas lever a little to insure that a charge of combustible gas will be inspired into the motor. The engine should be turned over several times as briskly as possible with the spark lever in full retard position and exhaust valves raised. The timer or contact breaker is then advanced slightly and the exhaust valves allowed to seat themselves. The hand crank is pushed in until it engages the ratchet member connected to the crankshaft, and then the motor should be turned by pulling up on the starting handle with the left hand.

The hand crank should always be engaged so that an upward pull will be necessary to turn the crankshaft, and a point that cannot be too firmly impressed upon the embryo motorcyclist's mind is that gasoline engines should always be started by pulling up on the handle of the starting crank, never by pushing down. If the starting handle has been properly placed and the engine has been turned over enough without the spark so the cylinders hold a gas charge, and the timer is advanced when a decided resistance is felt as the crank is turned indicating that the piston in the cylinder in which the gas charge is about to explode is nearing the compression point, a single, quick,

strong pull on the crank should be sufficient to start any properly adjusted motor.

All motorcycle motors have a certain degree of flexibility, i. e., they may be run slow or fast, and the speed may be accelerated or cut down as desired within a range from 200 revolutions per minute to the maximum, 2,500 or 3,000, which will vary with the type of motor. This is an important advantage, inasmuch as it permits one to regulate the cycle speed on most occasions by a touch of the throttle grip alone. The engine speed of practically all motorcycles is controlled by two ways, though usually these are employed in conjunction. One of these consists of varying the time of the spark in the cylinder, the other regulating the amount of gas supplied. The spark and throttle levers, while designed to be manipulated independent of each other, usually move with a certain definite relation. It would not be good practice to run an engine with the spark lever way advanced and gas supply throttle nearly closed; nor would good results be obtained if the spark lever was retarded and the throttle opened, as it is desired to increase the motor speed. It is not difficult to understand the function of the throttle lever and how the admission of more gas to the cylinders would act in creating more power, just as augmenting the steam supply to a steam engine will increase its capacity.

The rules for manipulation of the spark lever are not so well understood. In order to make clear the reason for intelligent manipulation of the spark handle, there are certain points that must be considered. On most motorcycles, there is a position of the spark lever at some point of the arc over which it moves which corresponds to the normal firing point. If the spark lever is not advanced beyond this position, and the motor is turning over slowly, the gas in the cylinders is being exploded when the pistons reach the end of their compression stroke. When the gas is fully compacted, the explosion or power obtained from combustion is more powerful than of the spark fired gas which was not compressed properly. The electric spark is not produced at the exact time that the motor should be fired at all speeds, and if the spark was supplied the very instant of full compression, irrespective of the speed of rotation, there would be no need of moving the spark lever.

Not only is the current apt to lag, but it takes a certain definite

amount of time to set fire to the gas. It requires the same amount of time to ignite the gas, of given composition, regardless of the speed of the motor. If the motor is only turning at a few hundred revolutions per minute, there is ample time to ignite all gas charges positively, but if the motor speed increases and the explosions occur oftener, then one must compensate for the more rapidly occurring combustion periods by arranging to start igniting the gas earlier so the explosion will occur when the piston is at its highest point in the cylinder. The compensation for lag is made by advancing the spark. The spark lever on the handle bar or tank moves a commutator, if battery system is employed, or the magneto contact breaker box, if that form of current producer furnishes the ignition energy. The amount of spark advance needed depends on engine speed and the greater the piston velocity the more the spark should be advanced.

It is possible to advance the spark lever too far, and, when this occurs, the gas is exploded before the piston reaches the top of its stroke, and premature explosion takes place. As a result of this, the upwardly moving piston is forced to overcome the resistance exerted by the expanding gas of the ignited charge in completing the remainder of the compression stroke, and before it will return on the power stroke. The injurious back pressure on the piston reduces the capacity of the motor and a pounding noise similar to that produced by loose motor parts gives positive indication of premature ignition due to excessive spark advance.

At the other hand, if the spark lever is not set as far forward as it should be, the explosion may be late because of the "retarded spark." If the spark occurs late in the cycle, the charge is not fired until the piston has reached its highest point and after it has completed a small portion of its downward movement. As the point of maximum compression is passed and the piston moves down in the cylinder, the size of the combustion chamber augments and the gas begins to expand again before it ignites. Owing to the moderate compression, the power resulting from explosions is less than would be the case with a higher degree of compression. To secure power, it is necessary to supply more gas to the cylinders. Driving with a retarded spark produces heating of the motor and is wasteful of fuel.

For ordinary running, the spark lever is usually placed about mid-

way of its travel on the sector, and as a general rule an engine with magneto ignition does not require the frequent manipulation of the spark necessary when current is produced by chemical means. As the engine speed increases, the current produced by the magneto is proportionately augmented, and the spark lever need not be advanced from the center position except under conditions which permit of exceedingly high engine speeds.

Summing up, it will be patent that the greatest economy of fuel will result when the motorcycle is operated with as little throttle opening as possible, and with the greatest spark advance the motor speed will allow. To obtain maximum power, as in hill climbing on the direct drive, the spark lever should never be advanced beyond center and the throttle should be opened as wide as possible. For extreme high speed, the spark is advanced as much as possible and the throttle opened wide.

Advice on Lubrication.—One of the most important considerations, making for efficient action and promoting long life of the mechanism, is to provide proper lubrication. The lubrication of the power plant is the most serious proposition. The best oil is the only kind that should be used, as more good motors have been ruined by the use of lubricant of improper quality or insufficient quantity than have been destroyed by accidents. If a drip feed is used, a medium grade oil may be employed in warm weather, but a light grade will be necessary in cold weather. If the supply is by mechanically operated pump, a heavier bodied lubricant may be used than when the drip feed system is employed. When oil is introduced to the engine crankcase by means of a hand-operated pump which means that lubrication is directly under the control of the rider, one pump full of oil, every 8 or 10 miles, at speeds of 20 miles per hour will be sufficient. For a speed of 30 miles per hour, it will be necessary to inject a pumpful every 5 or 6 miles. It is better to over-lubricate a machine than not to supply enough, so any time that the rider is in doubt it will be well to inject another pumpful on general principles. If the engine is over-lubricated, the exhaust will be smoky. If a mechanically operated oil pump is used and the hand pump is provided only as an auxiliary, it will not be necessary to supply oil except at such times that the engine is run exceptionally fast.

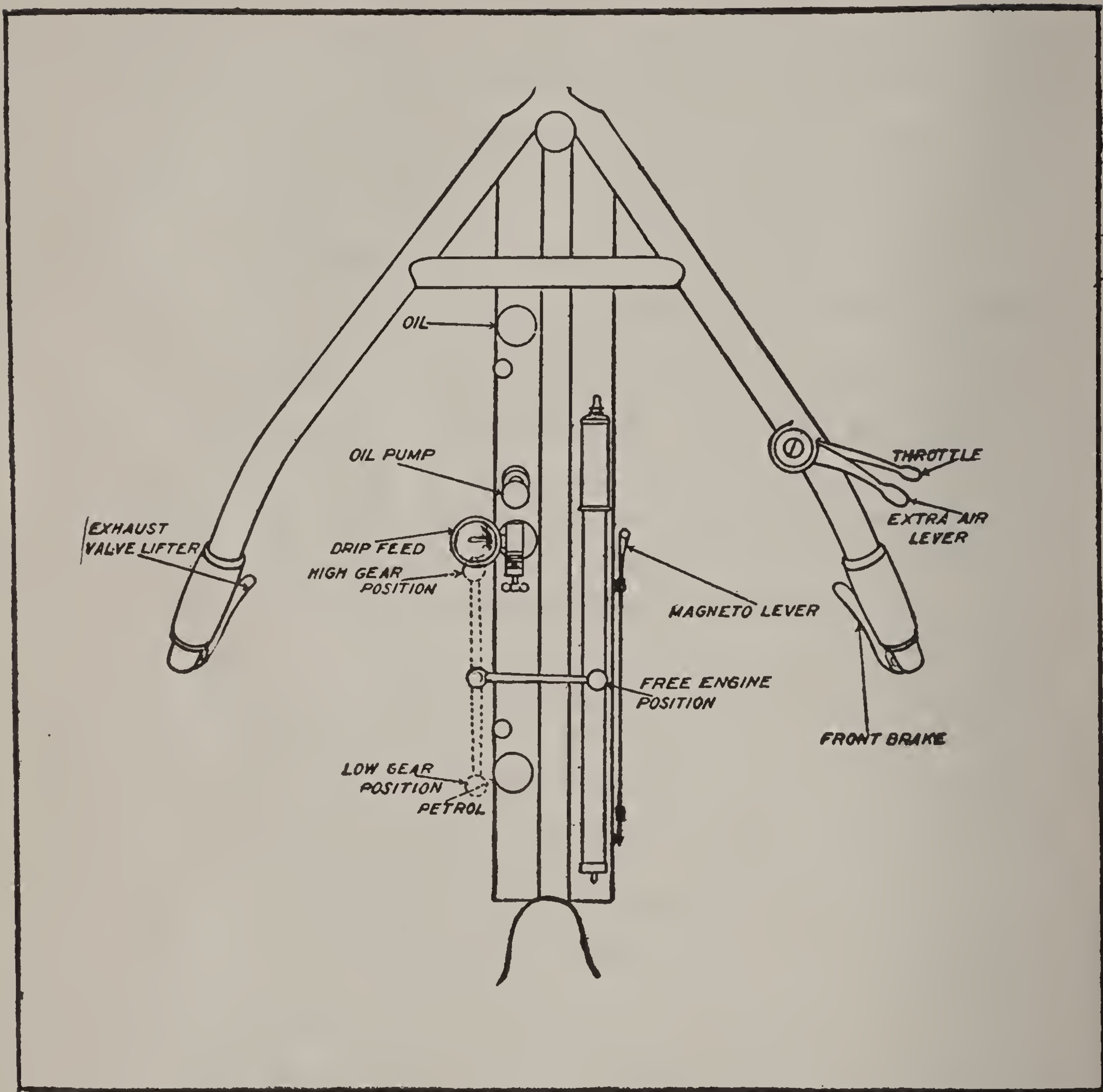


Fig. 325.—Diagram Showing Location of Control Levers on Royal Enfield Motorcycle.

Among some of the points that should receive oil every time the machine is used may be mentioned the valve lifters, or rocker arms, the free engine clutch, the steering head, and the various hinges and joints on the spring frame or spring fork. If a two-speed gear is provided the supply of lubricant should be renewed every 300 miles. Planetary gearing requires more lubricant and a lighter semi-fluid grease than either the sliding clutch or sliding gear forms. It is well to put a few drops of oil in the front hub and coaster brake oilers every day. About the only point on the motorcycle that can receive too

much oil beside the engine interior is the magneto, and only a few drops are required every two or three months to insure adequate functioning of this device. A special light oil is necessary for the magneto, and a good grade of sewing machine or 3 in 1 oil will be found satisfactory for this purpose. The hand oil-can may be filled with cylinder oil which can be used on all points of the machine, because if it is good enough for the engine interior, it is much better than needed for the various external parts. The ball bearings in the hubs, countershaft, and steering head may be packed with grease once or twice a season which will be adequate.

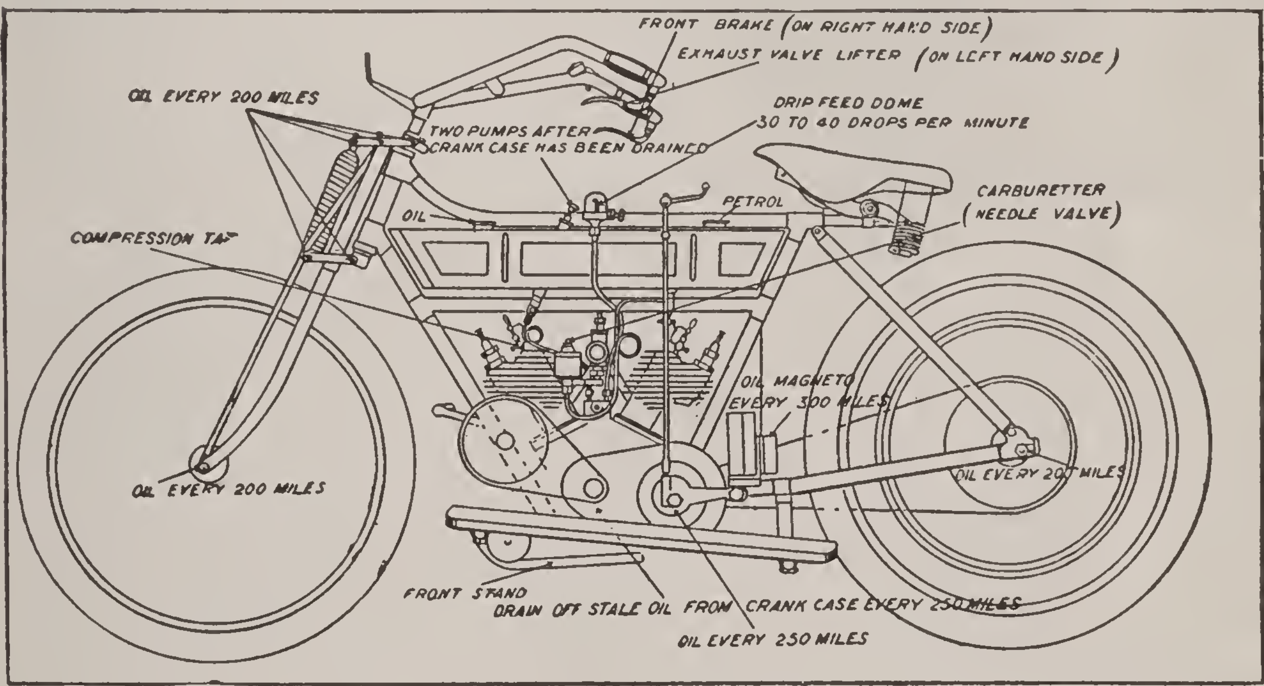


Fig. 326.—Diagram Showing Lubrication Points on the Royal Enfield Motorcycle.

A diagram at Fig. 326 shows the points on the Royal-Enfield motorcycle which demand lubrication. About the only point that needs to be explained is the drip feed system which is set to pass 30 or 40 drops per minute. When it is understood that this device is interposed in a lubricating system of the constant flow form in which circulation is maintained and the oil used over and over again it will be apparent that it would not make any difference if the lubricant passed through the sight feed glass in a steady stream. With the sight feed lubricators ordinarily provided on American machines, if these are set to feed faster than 10 or 12 drops per minute, the

engine base will receive too much oil, because there is no return pipe to direct the surplus lubricant back to the oil tank.

Motorcycle Troubles.—When the motorcycle was first evolved, it was a composite structure of two distinct assemblies, neither of which was adapted to the other. The gasoline motor could not be placed in the ordinary bicycle frame to advantage, and therefore gave continued trouble. As light bicycle frame construction was not sufficiently strong to withstand the vibration incidental to the motor, and greater speeds made possible by mechanical power, the early motorcyclist was confronted with two radically different species of troubles. While the most important of these were undoubtedly due to power plant defects, the annoyances caused by structural weakness of frame, wheels and tires were almost as numerous.

The individual peculiarities of the different machines preclude any specific outline of all derangements apt to occur, but a general outline of the common troubles may prove of value to the novice rider, regardless of the make of machine he rides. Motorcycle troubles may be divided into three main classes: those incidental to the power plant, the derangements of power transmission units and the difficulties encountered with the frame structure. In the first-named classification, the defects in the engine itself, and the auxiliary groups such as carburetion, ignition and lubrication, may be included. Troubles arising from belts or chains, sprockets or pulleys, clutches or two-speed gears are properly part of the second class, while frame, wheel, coaster-brake, spring fork and tire troubles are assigned to the third classification. It is with the first two that we have to deal mostly, because there are practically no structural defects in the modern machine, therefore of the third classification, we are limited almost entirely to tire troubles.

Classification of Engine Defects.—It is not difficult for one familiar with motorcycle construction and operation to make suggestions intended to assist the motorcyclist in locating troubles that may materialize with his power plant. The expert, as a rule, recognizes the symptoms of derangement, and usually has no difficulty in tracing the trouble to its source by well-known methods. The novice is often at loss to know how and where to begin to look for trouble and a safe rule for one with little mechanical experience to follow is

to search systematically for derangements and discover the fault that the expert would find through its symptoms by a patient process of elimination. The motorcycle power plant is really composed of several groups, each of which includes a series of distinct components. These are related so closely to each other that the failure of any one of the devices will affect the operation of the others and thus break the continuity of power production. Some auxiliary groups are more important than others, because the motor often continues to operate for a time after the failure of some essential parts in the group of lesser importance.

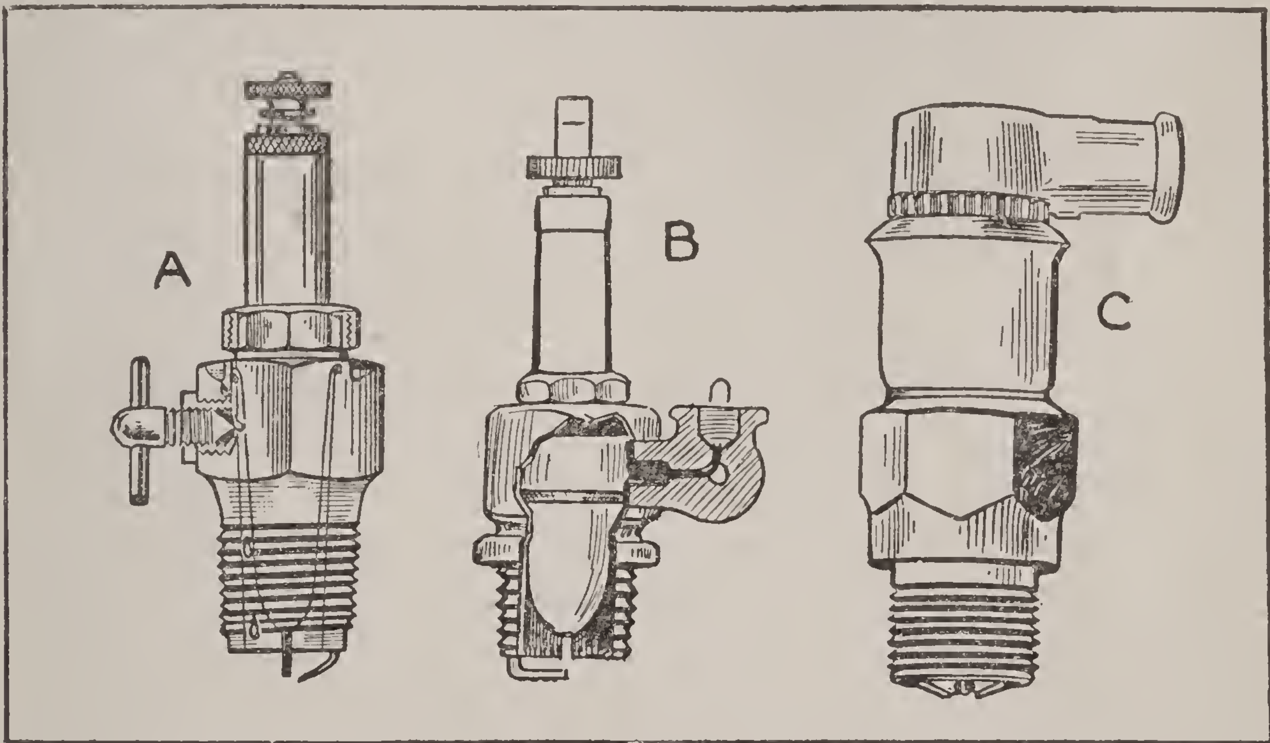


Fig. 327.—Combination of Spark Plugs and Priming Arrangements at A and B Facilitates Starting on Types of Motors Not Equipped With Compression Relief Cocks. Spark Plug With Water-Proof Terminal Shown at C.

While the internal combustion motor is a complete mechanism in itself, it cannot operate without some method of supplying inflammable gas to the cylinders and exploding the compressed charge to produce power. It will be seen, therefore, that the carburetor and ignition systems are really essential parts and that the engine will stop at once or work very irregularly if any component of either of these auxiliary groups fails to operate as it should. In order to keep the motor in operation, it is necessary to keep it cool, which, in a motorcycle power plant, is synonymous with supplying lubricant in

proper quantities to the moving parts to reduce friction. The motor would run for a time perhaps if lubrication was neglected, but overheating and frictional resistance would soon cause cessation of movement. It will be apparent that any defects in the fuel supply or ignition systems will make their presence known at once by affecting motor action, whereas a defect in the lubricating system might not be noticed immediately because the engine would run until it stopped because of overheating.

If a motor be inspected regularly and with any degree of care before a trip is commenced, there will be but little danger of serious trouble and any skipping or loss of power can be traced to failure of one of the components of the auxiliary systems rather than to a defect in the power plant itself. Irregular operation is seldom due to the actual breaking of any of the parts of the mechanism. Fortunately, depreciation, due to natural causes, comes slowly and deterioration of any of the mechanical parts always gives sufficient warning so that satisfactory repairs may be made before serious troubles occur. One of the most annoying troubles, and one that invariably denotes wear of the mechanism is continued noisy operation. The sharp metallic knocking that is so annoying to both experienced driver and novice, when not due to carbon deposits or preignition due to overheating or too highly advanced spark, indicates wear at either the main bearings or at the upper or lower end of the connecting-rod where the bushings may be worn so that considerable play exists between them and the shaft they encircle. A grinding noise accompanied by a knocking sound generally means that the lubrication system is not functioning properly or that the motorcyclist has neglected to inject the proper quantities of oil in the engine crank-case.

Before discussing the failures that may obtain in any particular part of the power plant, we will consider a case of engine failure, and, for the guidance of the novice, outline the main steps constituting a practical process of locating the trouble by systematic elimination. If the engine stops suddenly, the two main causes may be either failure of the gasoline supply or trouble in the ignition system. A sudden stop, when not due to overheating and seizing of the piston in the cylinder, which, as we have seen would be evidenced by a pronounced knocking long before the overheating became sufficiently great to

cause binding, is generally due to a broken wire or a defective spark plug. It can be caused also by the stoppage of the spray nozzle in the carburetor or the main fuel supply pipe with a particle of foreign matter.

Testing the Ignition System.—In a motorcycle, the simplest thing to test, in event of engine failure, is the ignition system, then the amount of motor compression, and lastly the fuel supply system. If the ignition system is working properly, as may be determined by laying the spark plug on the cylinder head and connecting it with the large wire leading from the magneto or coil and then pedaling briskly to see if there is any spark between the points of the plug, one should test the compression, and if this is satisfactory, the carburetor demands attention. The compression is tested by pedaling the engine over with the exhaust valve lift down, and if there is a decided resistance to turning at a certain point in the engine rotation, it is safe to say that there is no undue loss of gas.

Let us assume that in making our test with the spark plug on the cylinder that there has been no spark between the points of the plug. The first thing to inspect is the spark plug itself, where the following points should be carefully considered. First examine the gap between the points of the plug. This should be about 1/64-inch, if a magneto system is installed, or about 1/32-inch, if a spark coil and batteries are utilized to produce the spark. With a battery ignition system, one should examine carefully all the wires to see that they are tight on their terminals, and that none of the wires have become short-circuited by burning away of the insulation, which may have been in contact with a hot exhaust pipe or cylinder head flange. The vibrator or contact spring at the timer may be adjusted poorly, which would mean that contact would not be established properly, while the spark plug might become short-circuited because of cracked porcelain insulation or carbon deposit. Short-circuiting will also occur in mica plugs if the insulator becomes oil-soaked.

With battery ignition, the source of current should be tested with an ammeter to determine if the dry cells have sufficient amperage to insure regular ignition. If they indicate less than 5 amperes a cell, new ones should be used. A good way to see if current is present at the timer is to bridge the insulated contact screw on the timer case

to the crankcase by means of a screw-driver, with the switch plug in place, and observe if there is any spark as the screw-driver end is rubbed over the engine base. If a spark is present at this point, it is reasonable to assume that the trouble is due to defective spark plug or to a defective secondary wire leading from the coil to the plug.

If a magneto be used, it is possible also for troubles to exist at the spark plug as previously enumerated, or the ground wire may make contact with the metal of the frame before it reaches the cut-out switch. The platinum contact points in the breaker box, which is the part rocked back and forth as the timer lever is moved, may be out of adjustment; the carbon contact brushes that convey the current from the revolving armature to the terminal by which the device is connected to the spark plug may be broken or not making contact, or the insulation of the secondary wires may be defective.

Common Faults in Carburetion System.—If the trouble is not due to the ignition system, and there is good compression in the motor, the carburetor demands attention. The first thing to look for is to see that there is plenty of gasoline in the tank, as many a novice has exerted himself unduly trying to make an engine start when there was no fuel in the container. If the tank is found to hold a sufficient supply of fuel, the next thing to do is to make sure that the pipe line is clear to the carburetor. This may be ascertained easily by shutting off the gasoline at the tank, uncoupling the gasoline pipe at the carburetor, and then turning the supply on to see if any issues from the pipe. If the gasoline runs out in a full stream when the valve is opened, the pipe is clear; whereas, if it trickles out but slowly, one may assume that the bore of the tube is constricted by becoming dented or by dirt.

One may often determine if the gasoline supply is all right by pressing on the little priming pin on the carburetor float bowl until gasoline drips out of the bottom of the carburetor or the air intake. This is called flooding the carburetor. If, on the other hand, the carburetor floods continually without the priming pin being depressed, it constitutes a defect that will produce other troubles, though not always stoppage of the motor. Among other causes that might cause engine to stop one should see that the throttle has not become closed through the failure of a connecting link or operating wire and that the

shut-off valve in the feed pipe has not jarred closed. The gasoline may reach the carburetor all right and yet there may not be enough liquid in the float chamber of the device. This would happen if the action of the float-controlled needle valve was interfered with by dirt or binding, if the float was badly adjusted or if the float valve operating mechanism was worn unduly in some forms of carburetor.

Causes of Lost Compression.—Assuming that we have found both ignition and carburetion systems to be functioning properly and that the motor has no compression, then the trouble is due to some condition either inside or outside of the motor. As the external parts may be inspected with greater ease, one should look for the following: Sticking or bent valve stem, broken valve spring, leak through spark plug compression release cock or valve dome, valve plunger stuck in its guide keeping valve open, lack of clearance between valve stem end and operating plunger or tappet-rod and in very rare instances a cracked cylinder head or leaky cylinder head gasket where the head is separate from the cylinder. Among some of the defective conditions that may exist inside of a motor are: a broken valve, a warped valve head, foreign matter under valve seat, piston rings broken or gummed in the piston grooves or scored or worn cylinder.

Causes of Irregular Motor Operation.—If the engine works irregularly or skips, the cause may be harder to locate because many possible conditions may exist that must be eliminated and checked over one by one. In addition to the troubles previously enumerated, a very common cause is an air leak around the induction manifold, dirt in the carburetor or improper mixture. The gasoline needle may be set improperly or may have jarred out of adjustment or the air valve spring may have been weakened or broken. The air intake dust screen may be so full of dirt and oil that not enough air will pass through the mesh. There may be water or sediment in the gasoline which would cause irregular operation because the fuel supply would vary at the nozzle.

Where a magneto ignition system is employed, it is seldom that one finds defects in the magneto, but when batteries are used just as soon as they become weakened the engine will begin to miss fire. Another thing that must be done very carefully is adjusting the contact screw at the timer as many puzzling cases of irregular ignition with battery

systems have been corrected by cleaning the oil out of the timer, washing the interior out thoroughly with gasoline, and then readjusting the points while the engine was running. Points may be screwed nearer together, and if this does not correct the trouble they may be separated very gradually. When the proper adjustment is reached, the engine will accelerate and run smoothly. (See instructions in chapter on ignition for magneto contact breaker adjustment.)

Conditions Producing Overheating.—Overheating is usually caused by carbon deposits or derangement of the lubrication system. It is sometimes caused by carburetor troubles as well as insufficient oiling. The lubricating system of the average motorcycle is extremely simple, consisting of a simple hand pump by which oil may be injected into the crank-case when desired, and an auxiliary oil feed to the cylinders by means of a hand regulated sight feed drip valve at the tank. The conditions that most commonly result in poor lubrication are: Insufficient supply of oil in engine base, use of poor quality oil, clogged oil pipe, defective check valve or worn plunger at the pump, clogged sight feed fitting, and if a mechanical oiler be employed, a broken pump, or a defective drive.

Any condition that will cause too rich mixture will also result in overheating. These may be enumerated briefly, as follows, too much gasoline in the mixture due to improper needle valve regulation, level in float chamber too high or auxiliary air valve spring too tight. A cork float may be fuel-soaked, or a hollow metal float may leak and be full of liquid which increases the weight and causes the carburetor to flood. Dirt will also keep the float-controlled needle valve from seating, and the level be too high at the standpipe, or, as previously outlined, the air screen may become clogged with dust and not enough air reach the mixture. If there is an excessive amount of carbon present in the combustion chamber and on top of the piston, this will also produce overheating and preignition. These deposits should be removed from the piston top and combustion chamber wherever present. Many cases of lost power which also causes overheating have been corrected by merely grinding in the valves to a correct seating. Overheating has been caused also by a worn or poorly adjusted valve plunger which did not raise the exhaust valve from its seat sufficiently, or by altered spark timing which meant

operating the motor on a late or retarded spark or late exhaust valve opening.

Some Causes of Noisy Operation.—There are a number of power-plant derangements which give positive indication because of noisy operation. Any knocking or rattling sounds are usually produced by wear in connecting rods or main bearings of the engine, though sometimes a sharp metallic knock, which is very much the same as that produced by a loose bearing, is due to carbon deposits in the cylinder heads, or premature ignition due to advanced spark-time lever. Squeaking sounds invariably indicate dry bearings, and whenever such a sound is heard it should be immediately located and oil applied to the parts thus denoting their dry condition. Whistling or blowing sounds are produced by leaks, either in the engine itself or in the gas manifolds. A sharp whistle denotes the escape of gas under pressure, and is usually caused by a defective packing or gasket that seals a portion of the combustion chamber or that is used for a joint as the exhaust manifold. A blowing sound indicates a leaky packing in crank-case. Grinding noises in the motor are usually caused by the timing gears, and will obtain if these gears are dry or if they have become worn. Whenever a loud knocking sound is heard, careful inspection should be made to locate the cause of the trouble. Much harm may be done in a few minutes if the engine is run with loose connecting-rod or bearings that would be prevented by taking up the wear or looseness between the parts by some means of adjustment.

Valve Removal and Grinding.—The operation of valve grinding is a simple one provided that the valve seat is not too badly pitted or scored. The first step is to remove the valve from the cylinder, which is not difficult with the usual forms of inlet valves, as it is merely necessary to remove the dome in which they are housed. To facilitate the removal of the exhaust valve, tools such as shown at Fig. 328 may be employed to compress the valve spring and permit the removal of the pin or key at the bottom of the valve stem. With the form shown at A, it is necessary to hold the exhaust valve down as the spring is raised, which may be easily done by interposing a small block of wood, belt connector, chain link or other object between the valve cap and the valve head or by holding the head down against

the seat with the screw-driver or other tool. With the valve lifter shown at B, the hook member supporting the fork or lever that raises the spring holds the valve against the seat. If the valve face is badly scored or pitted, it may be found desirable to reface that member before endeavoring to grind it in. This may be done by a simple tool as shown at Fig. 329. A cutting blade is carried by a casting which also serves to support the valve stem at one end and a screw at the other by which the valve head may be brought in contact with the angularly disposed shaving cutter. As the valve is rotated by the dog attached to the valve stem, the seat will be trued off to the proper angle. Valve grinding consists merely of smearing the face of the

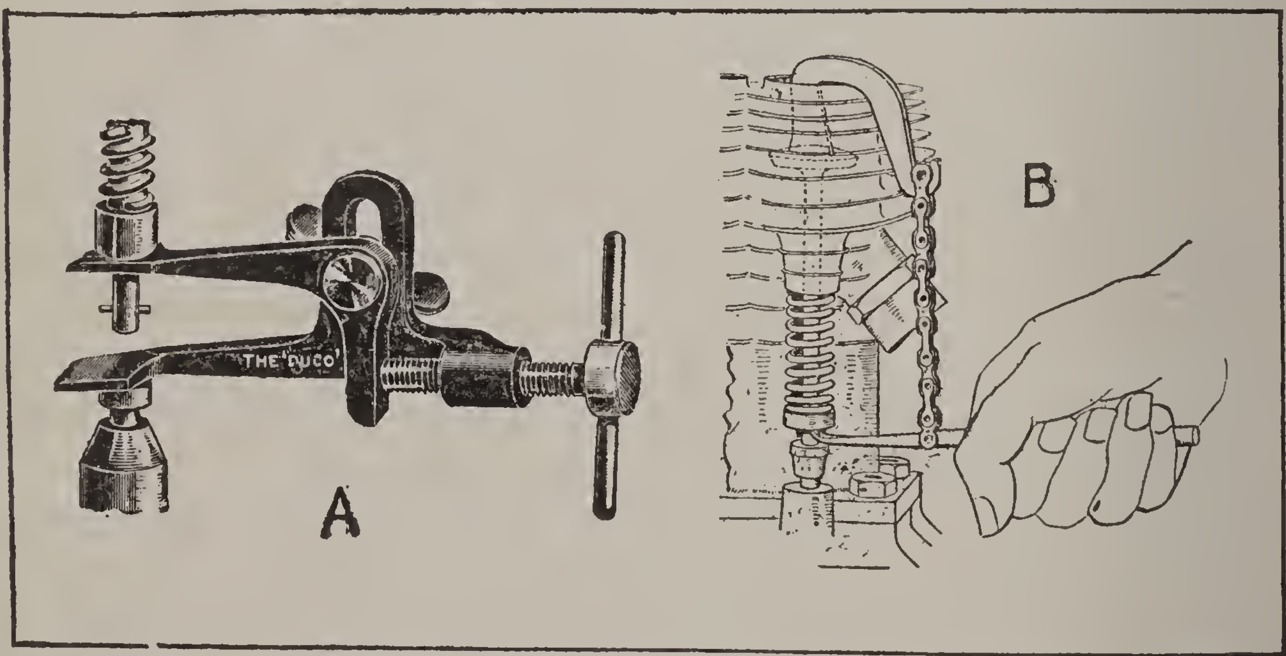


Fig. 328.—Two Methods of Raising Exhaust Valve Spring to Permit Valve Removal.

valve and the seating with a mixture of emery and oil, and rotating the valve against the seat by a screw-driver. The valve is lifted from time to time and fresh abrasive supplied every time that the valve and its seating are cleaned off with gasoline to see what kind of a bearing is obtained. When the valve has been properly ground in, it will have a bright ring around the entire circumference of the face and the valve seat in the cylinder will show a correspondingly bright surface. Among the precautions to be observed, an important one is to prevent the emery getting into the cylinder by putting a plug or bunch of waste or cloth in the passage between the valve chamber and combustion head. It is also best to use a fine grade of emery or

ground glass and not to bear down unduly on the screw-driver or grinding tool. It is better to oscillate the valve than to turn it around completely because when the valve head is moved a portion of a revolution and back again it is not so apt to roll the abrasive up into a ball that may cut ridges in the valve seat.

Removing Carbon Deposits.—If the motor is of a detachable head form, it is a comparatively simple matter to remove the combustion head which will expose the piston top as well as the combustion chamber. The carbon deposits, which are a fertile source

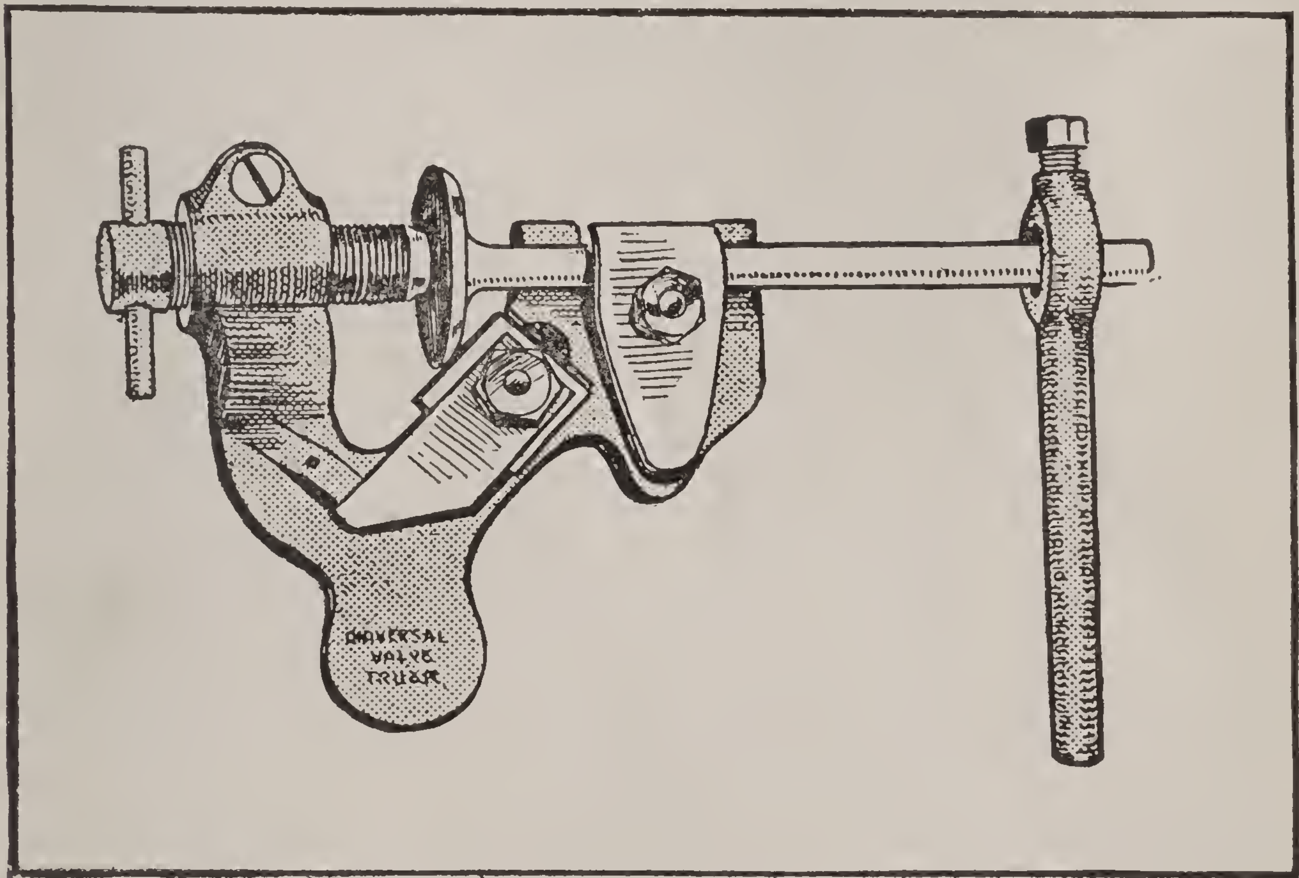


Fig. 329.—Simple Tool Used in Refacing Valve Seat.

of trouble, may be removed by positive mechanical means, such as indicated at Fig. 330, A, in which a screw-driver, chisel or scraper is employed to scrape them off. As the combustion head is removed, it will not be difficult to relieve it of carbon deposits in the same manner. If a one-piece cylinder is employed, that member may be removed, as shown at Fig. 331, which will expose the piston top and the combustion chamber interior for mechanical scraping.

A new process of carbon removal which is meeting with success is shown at Fig. 330, B. This calls for the use of a small torch burning

ordinary gas or an ordinary match to start combustion, and another member that will supply oxygen to the interior of the combustion chamber. The stream of oxygen permits combustion of the deposit and the carbon is burnt out at all points where the flame touches, passing out of the cylinder in the form of a gas, and leaving only a fine residue or dust in the combustion chamber, which is blown out with the exhaust as soon as the engine is started. As the application of the oxygen process does not necessitate dismantling the engine, it may be used to considerable advantage, especially with the one-piece cylinder construction.

Instructions for Running De Luxe Motors.—As the Spacke motors are so generally fitted to motorcycles and cyclecars, the

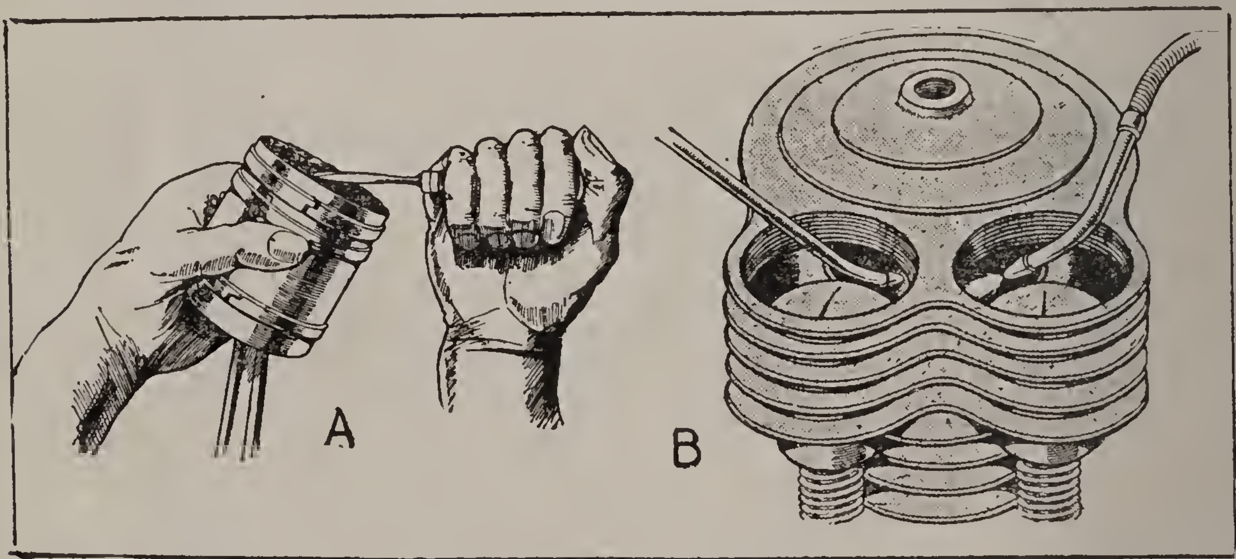


Fig. 330.—Methods of Removing Carbon Deposits From Piston Top or Combustion Chamber Interior.

following instructions, furnished by the makers, may prove of value to the riders using this well-known power-plant equipment.

Any motorcycle motor, by reason of its relatively light weight and high speed of operation, requires a consistent amount of care to insure long life and satisfactory operating service. Care should be exercised to see that all adjustments are properly taken care of, and that the motor is at all times supplied with the proper amount of lubricating oil. Oil is always cheaper than repairs. Keep the motor clean. Avoid racing motor when using the free engine clutch or when running on stand, and prevent untimely depreciation. Watch oil tank and sight feed to make certain that the motor is getting its supply of oil.

Keep spark fully advanced and regulate speed by the throttle,

except when ascending a bad hill, spark should be retarded enough to prevent motor from knocking. Avoid using too rich a mixture, as the unburned gasoline carbonizes in cylinder. After each 500 miles is ridden, old oil should be drained from crank-case, and latter should be flushed out with kerosene. Refill crank-case with oil to bottom of oil window before running again.

De Luxe motors should always be lubricated with a sight feed drip,

Fig. 331.—Accessible Design of Rudge-Multi Motorcycle Permits the Removal of the Cylinder Without Disturbing Position of Engine Base in Frame.

fastened to oil tank and connected to ball valve between the cylinders on the twin, and behind the cylinder on the single. If a hand oil pump is provided, it should be connected to the drip feed tube just above ball valve, by means of a "Y" or "T" connection. The sight feed should be set to drop about 8 drops per minute for the single-cylinder and about 12 drops per minute for the twin-cylinder motor. However, the amount varies with the quality of oil and the speed, and the

rider should make sure that the motor is always getting enough oil, but not so much as to cause excessive smoking. Cap over inlet valve rocker arm should be removed occasionally, and the space packed with hard grease and graphite.

To facilitate starting in cold weather, motor may be primed by removing the rocker arm cover screw nearest the carburetor, and a small amount of gasoline injected into the screw hole.

Clearance between push rods and valves should be kept about .007 inch, which is about equal to two thicknesses of newspaper. This will insure quiet running and correct timing.

To time valves, turn crankshaft forward until piston arrives 7/16 inch from bottom of stroke, and hold in this position. Turn cam shaft outward from motor until exhaust push rod is lifted against valve stem. Replace crankshaft timing pinion, so that mark corresponds with mark on cover, when pinion is in place. Replace nut and cotter. As the spiral teeth of the pinion cause it to rotate to the left while being pushed into place, it must be started a quarter turn to the right of its correct final position.

To set magneto after valves are timed, turn crankshaft forward until piston arrives 3/8 inch from top of compression stroke. Set magneto timing lever to full advance; turn armature toward motor until interrupter contacts start to separate. Replace magneto drive gear on cam-shaft, so that mark on gear corresponds with mark on cover when gear is in place. Replace nut and cotter. This gear rotates to the left while being pushed into position and must be started 1/6 turn to the right of its correct final position. On twin motors, the rear cylinder should be used for both valve and magneto timing. Removing cover from crank-case disturbs the timing of the valves, necessitating retiming, but does not affect the magneto setting, which is only disturbed when magneto is removed from pad. Magneto on the twin is marked I and II just above cable terminals. I should be connected to rear cylinder, and II to front cylinder.

It is important that the nut holding driving pulley or sprocket on crankshaft be kept tight, as this nut holds left fly-wheel in position. Special wrenches are furnished with each motor.

Defects in Power Transmission Elements.—If the drive is not positive when chains are employed, the trouble is invariably due to

a slipping clutch or compensating sprocket which may be easily remedied by adjusting these devices. If chains break frequently, it is because they are either worn unduly, sprockets are not in proper alinement, or the sprockets have depreciated to such a point that the teeth are hooked and do not permit the chains to ride smoothly over them. Chains should be kept clean and thoroughly lubricated in order to obtain silent driving. Lubrication does not consist of indiscriminate application of oil over the chain surface, but should be done by removing the chains, cleaning them thoroughly in gasoline or kerosene, and then boiling them in tallow or a mixture of grease and graphite. After the chains have been allowed to soak in this hot mixture, they are taken out and the surplus lubricant wiped off the outside. Oil on the chain surfaces merely serves as a basis for accumulations of dirt which act as an abrasive and produces rapid wearing of both chains and sprockets.

Testing for Chain Alinement.—There are two ways in which alinement may be at fault. The sprockets may be in line, but the shafts may be out of parallel. On a well-designed machine, this should not happen, but cases have been known. The second possibility is that the shafts may be parallel, but one sprocket further in or out on the shaft than the other.

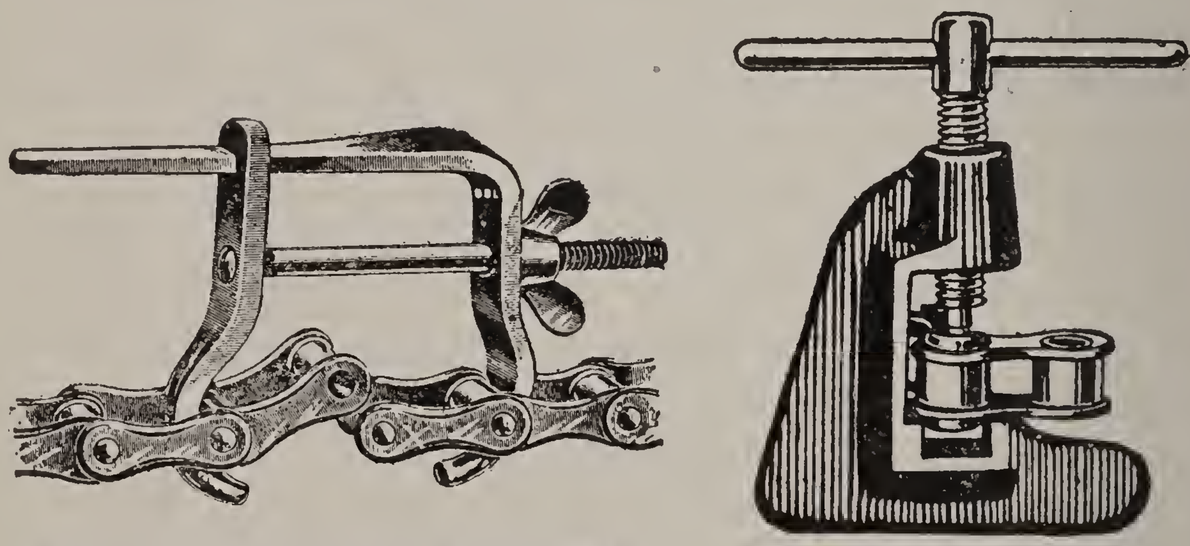
In order to discover if the alinement is correct, the inside of the side plates of the inner links of the chain should be examined after the chain has been in use some little time. If the side plates on one side of the chain are worn much more than those on the other, with ridges or shoulders cut in them by the wheel teeth, the probability is that one of the shafts is a little out of parallel. Should both sides of the chain be unduly worn and cut, probably one wheel is further out on its shaft than the other. A straight edge, or even a piece of string stretched tightly across the faces of both wheels, will often indicate the error. Generally speaking, errors in alinement are best corrected by the expert, i. e., the machine should be taken to the agent for examination.

How to Adjust Chains.—If the chain is too slack, it is apt to "whip," which intensifies the wear and tends to break the rollers. If, on the other hand, it is too tight, a crushing effect is produced on the rollers, and the whole chain is strained unduly. A chain should

be adjusted, and kept adjusted, so that it can be pressed down with the finger from ⅛ inch on the short drive from engine to countershaft, to, say, ½ inch on the back chain.

Adjustment of the first reduction drive is generally provided for by an eccentric on the countershaft, or by sliding the gear box. The slack in the back chain is taken up in the same manner as on the pedal cycle by drawing back the rear wheel. Of course, the tension of all chains should be looked to at the same time.

Slipping Belt Drive.—Flat belt drive is well thought of but has the defect of slipping at times. It is imperative that the belt be kept



Motor Cycle Chain Puller with Fly Nut.

Chain Rivet Punch.

Fig. 332.—Tools Used to Facilitate Repair of Motorcycle Drive Chains.

soft and pliable at all times with applications of neatsfoot oil, and that the lagging on the small pulley be maintained in proper condition. When the lagging wears off, the belt will not have sufficient adhesion with the small metal pulley, and slipping is unavoidable. Various special laggings composed of woven asbestos materials impregnated with rubber are marketed at the present time which give much more satisfaction than leather, as they are more enduring and have a greater degree of friction. The V-belt transmits power positively and only slips when the pulleys are worn so that the belt does not contact properly with the pulley sides. The design of the V-belt is such that it has a certain wedging action in the pulley and is not apt to

slip as is the flat belt. If the clutch is at fault as is the case if the belt or pulleys are not worn unduly, it can be taken up until it transmits power without slipping.

Care of Leather Belts.—Clean your belt thoroughly and often, once a week, or at least after every hard run. Carefully scrape off all dirt or sand.

After each cleaning, apply motorcycle belt dressing. This dressing will increase the life and efficiency of your belt—keep it soft and pliable, and prevent unnecessary slippage, which will wear out any belt.

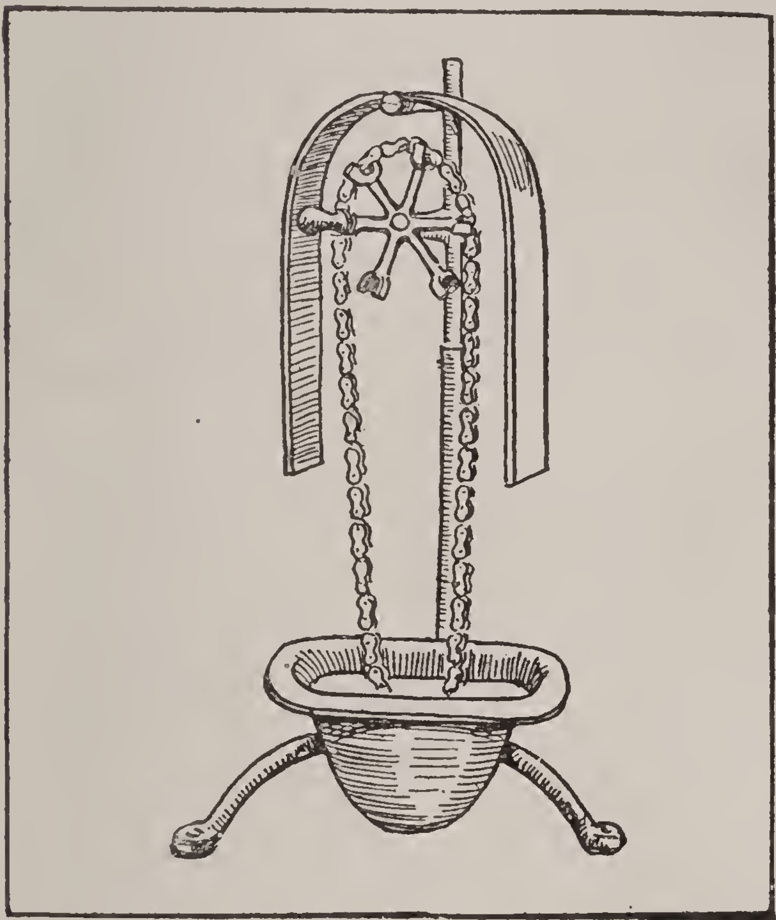


Fig. 333.—The Noonan Chain Bath, a Handy Device for Cleaning Motorcycle Drive Chains.

It is important that the screws in pulley lagging do not project; if they do, they will cut the belt and shorten its life.

Be sure to release the idler when machine is not in use, and apply carefully when in service —this warrants minimum stretch of belt, and enables it to retain its elasticity and wear longer.

Care of Wheels.—The important point to observe in regard to the wheels is that these are adjusted so that they revolve freely. If the cones of the hubs are screwed up too tightly, the ball-bearings will have considerable friction and will wear out rapidly. The hub bearings should always be kept properly lubricated, and the cones should never be tightened up beyond the point where the wheel will revolve freely and yet have no side-play or shake. Where the drive is through the hub, as is the case in all chain-driven machines, one should inspect the rear wheel carefully from time to time for loose spokes. With a belt-driven machine, this precaution is

not so necessary because the power is applied to a large belt pulley attached directly to the rim and not through the medium of the hubs and spokes. The front hub, if properly adjusted, is not apt to give any trouble, but the rear wheel which has a coaster-brake hub needs more attention. It not only demands more oil and careful adjustment of the hub bearing, but the braking mechanism must be looked at from time to time to make sure that the brakes will function properly when needed. If the brake does not engage promptly, it indicates that the brake end is filled with an accumulation of old, gummed-up lubricant. If the brake takes hold too quickly, it indicates lack of lubrication in brake end. If hub runs hard, it indicates that adjusting cone is too tightly screwed in; if hub wabbles, it means that bearings are adjusted too loosely. If forward pedaling does not engage hub and rotate it promptly or back pedaling does not apply brake positively, examine transfer spring to see that it is not broken and that it is in place correctly.

Common Defects in Clutches.—Considering first the member of the transmission system that will affect the efficiency of the entire assembly when deranged, it will be well to discuss the troubles common to the various types of clutches. The defective conditions that most often materialize are too sudden engagement which causes "grabbing," failure to engage properly, slipping under load, and poor release. Clutches utilizing a leather facing will cause trouble after a time, because of natural wear or some defect of the friction facing. The leather may be charred by heat caused by slipping, or it may have become packed down hard and have lost most of its resiliency. The clutch spring may be weakened, or broken; this will cause the clutch to slip even if the leather facing of the cone is in good condition. The two troubles usually met with by the motorist are harsh action, as one extreme condition, and loss of power through slippage as the other.

When a cone clutch engages too suddenly, it is generally caused by the surface of the leather lining becoming hard and not having sufficient resiliency to yield to some extent when first brought into frictional contact. To insure gradual clutch application, the facing should be soft and elastic. If the leather is not burned or worn unduly, it may often be softened by rubbing it with neatsfoot oil. Kero-

sene oil is often enough to keep the clutch leather pliable, and it possesses so little lubricating value that the clutch members are not liable to slip because of a reduced coefficient of friction such as often caused by the application of more viscous lubricants. Kerosene has other advantages, among which may be mentioned quick penetration of the leather and not collecting grit or gumming.

When a cone clutch slips, it is usually due to a coating of oil on the frictional material that decreases the value of the coefficient of friction to such a point that the pressure of the clutch spring is not enough to maintain sufficient frictional contact between the male and female members to insure driving. The remedy for this condition is to absorb the surplus oil by rubbing a small quantity of fuller's earth into the leather surface. When the clutch cone is in place, it is not easy to reach the surface of the leather, so the first step would be to disengage or release the clutch and to place enough of the fuller's earth on a piece of paper or card so it can be sprinkled into the space left between the male and female members when the former is properly released. Borax is sometimes recommended for the same purpose, and when the earth or borax is not available the carbide dust or lime residue from the acetylene gas generator may be used to advantage. If slipping is caused by weakening of the clutch spring, it may be prevented by substituting springs of proper strength or by increasing the degree of compression of the weak springs by the means of adjustment often provided for the purpose.

Another annoying condition that sometimes obtains when a cone clutch is used is spinning or continued rotation of the male member when clutch spring pressure is released. This may be the result of natural causes, but it is sometimes caused by a defect in the clutch mechanism. If the bearing on which the cone revolves when disengaged seizes because of lack of lubricant the male member of the clutch will continue to rotate even when spring pressure is released. The ball-thrust bearing employed to resist spring tension may become wedged by a broken ball, and this will cause the rotation of the crankshaft to be imparted to the cone member through the spring, which must turn with the crankshaft instead of remaining stationary, as would be the case if the ball-thrust bearing was functioning properly.

On those motorcycles fitted with multiple-disc clutches, the same

troubles may be experienced as with other types. If a multiple-disc clutch does not release properly, it is because the surfaces of the plates have become rough and tend to drag. The plates of a multiple-disc clutch should be free from roughness, and the surfaces should always be smooth and clean. Harsh engagement also results by the absence of oil in those types where the discs are designed to run into an oil bath. Spinning or continued rotation of a multiple-disc clutch often results from seizing due to gummed oil, the presence of carbon or

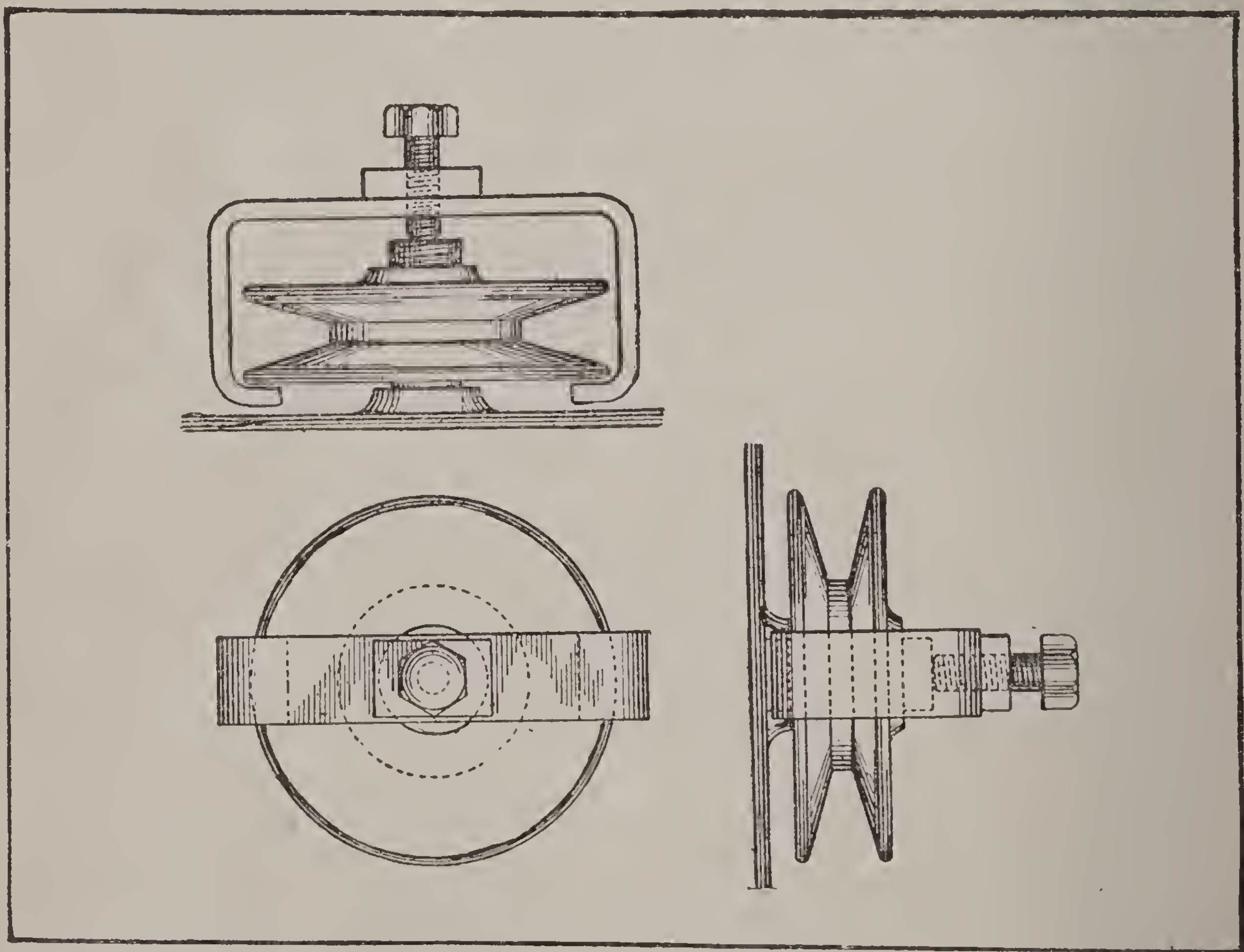


Fig. 334.—Diagram Showing Construction of Simple Puller for Removing V Pulleys or Sprockets From the Taper on End of Engine Crankshaft.

burned oil between the plates and sometimes by a lack of oil between the members. When a multiple-disc clutch slips, it is generally caused by lack of strength of the clutch springs or distortion of the plates. To secure the best results from a multiple-disc clutch, it is imperative that only certain grades of oil be used. If one uses a cheap or inferior lubricant, it will gum and carbonize, because of the heat present when the plates slip or it will have such viscosity that it will gum up between

the plates. Most authorities recommend a good grade of light or medium cylinder oil in multiple-disc clutches where lubricant is required. In some cases, faulty multiple-disc clutch action is due to "brooming," which is the condition that exists when the sides of the keyways or the edges of the disc become burred over and prevent full contact of the plates. Clutch plates with friction facing, such as Raybestos, are intended to be run without lubricant, and will be apt to slip if oil is put in the clutch case. When the frictional material wears, it must be replaced with new. New facings or discs may be obtained from the motorcycle builder much cheaper than from other sources.

Derangements in Change Speed Gearing.—As previously explained, the simplest form of gearing to obtain various speed ratios in cyclecars is the friction-disc type. Failure to drive properly may result from excessive oil on either the face of the driving disc or the periphery of the driving wheel, lost motion, wear or spring at various points in the operating mechanism, or deterioration of the surfaces of either driving discs or driven wheel. If trouble is experienced in a friction transmission, the first point to inspect is the condition of the friction surfaces. If excessive deposits of oil have caused slipping, it should be thoroughly removed with gasoline and the surface of both disc and wheel sprinkled with talc powder. If the face of the aluminum alloy driving disc is grooved or roughened, slipping is inevitable until the disc is refaced absolutely true. The strawboard fiber friction band of the driven wheel may "broom" out, and this will cause slipping because the surface is not true. As a general rule, the fiber ring of the friction transmission should be renewed after it has been used from 4,000 to 5,000 miles. Wear at the countershaft bearings will produce a tendency for the driven wheel to crowd toward the center or edge of the driving disc, depending upon the relation of the actual line of contact with the theoretical contact line drawn through the disc. Lost motion or spring in the parts serving to engage the friction surfaces will cause slipping because the degree of pressure necessary to secure the frictional adhesion required between the members to secure positive driving will be reduced.

The chief trouble with a planetary transmission of the type used on motorcycles and cyclecars is caused by slipping clutch bands. These

are provided with adjustments that can be tightened in case of wear, and should grip positively. If either the slow or reverse bands are adjusted too tight, they will bind on the drums and produce friction, which, in turn, will decrease the efficiency of the drive. Noisy action of planetary gearing is usually caused by lack of lubrication or excessive wear in the gearing. If the oiling is properly taken care of this condition will be practically eliminated. Sometimes the high-speed clutch may slip, but most planetary gears are provided with adjustable clutches so any wear may be readily taken up.

When sliding-gear or shifting clutch transmissions are used, the most common defect is difficulty in shifting gears and noisy operation. The trouble met with in gear shifting is usually caused by the edges of the teeth of the shifting members having burred over so that they do not pass readily into the spaces between the teeth of the gears they engage with. Another cause of poor gear shifting is deterioration of the bearings which may change the center distances of the shafts to a certain degree and the relation of the gears may be changed relative to each other so they will not slide into mesh as freely as they should. Noisy operation is usually due to a defective condition of lubrication, and if the gears are not worn too much it may be minimized to a large extent by filling the gear case with oil of sufficient consistency to cushion the gear teeth and yet not be so viscous that it will not flow readily to all bearing points. A difficulty in shifting is sometimes due to binding in the control levers or selective rods, and these should always work freely if prompt gear shifting is required. If considerable difficulty is experienced in meshing the gears and the trouble is not found in the gear-set, it will be well to examine the clutch to make sure that the driven member attached to the gear-set main shaft does not "spin" or continue to revolve after the clutch is released.

Adjustment of Brakes.—The means of adjusting brakes may be easily ascertained by inspection. If brakes do not hold properly, and the friction facing is in good condition and free from oil, the failure to grip the drum is probably due to wear in the operating leverage. On some form of brakes, notably those which are expanded by a cam motion, compensation for wear of the brake shoes is often made by shortening the rods running from the brake to the operating lever. External brakes are usually provided with an adjustment on the brake

- **ENGINE WILL NOT START**
  - **Carburetter floods on depressing float needle**
    - Spark at plug
      - Spark too weak under compre
      - Short on plug, or lead.
    - No spark at plug
      - Spark at terminal
        - Faulty plug.
        - Sooted plug po
        - Weak spark.
        - Short circuit.
      - No spark at terminal
        - Breaker arm st
        - Breaker arm free
          - Dirty platinum
          - Faulty contacts
          - Failure in mag snlation.
          - Broken carbon
  - **No petrol at carburetter**
    - Controls sticki
    - Incorrect timi
    - Air leakage.
    - Petrol tap clos
    - Petrol tap open
      - Choked pipe.
      - Pipe clear
        - Dirt in jet.
        - Air lock in tan
        - Float needle st

- **ENGINE RUNS IMPERFECTLY**
  - **Lacks power**
    - Constantly
      - Controls out of
      - Controls in order
        - Poor compressi
        - Valves need gr
        - Valve springs
        - Stretched exha
        - Choked silence
        - Incorrect valve
        - Gear too high.
        - Bad air adjust
        - Obstruction in pipe.
        - Excessive car posit.
    - At intervals
      - Partial obstruc petrol.
      - Carburetter too
      - Sticking valve
  - **Engine knocks**
    - Pre-ignition.
    - Overheating.
  - **Misses fire**
    - Spark irregular
      - Sooted plug.
      - Dirty breaker
      - Occasional sho
    - Spark regular
      - Mixture too we
      - Water in petro
      - Starved carbur
  - **Fails on hills**
    - Too high a gea
    - Correct gear ratio
      - Engine dirty.
      - Engine clean
        - Stretched valv
        - Sooted plug.
        - Ignition too far
        - Too much air.

- **ENGINE STOPS**
  - No petrol.
  - **Petrol**
    - Spark at plug points
      - Compression
        - Carburetter working
          - Broken valve re on seat.
          - Broken valve sp
          - Controls not w
          - Overheating.
          - Insufficient lub
          - Air leakage.
          - Stripped timing
        - Carburetter not working
          - Choked jet or p
          - Punctured float
          - Flooded float ch
          - Air lock.
          - Binding needle.
      - No compression
        - Broken valve.
        - Broken piston r
        - Piston ring slot
        - Piston rings gu
        - Valve sticking
        - Broken piston, c rod, or crank
        - Pitted valve fac
    - No spark at plug points
      - No spark at magneto
        - Sticking breake
        - Breaker arm free
          - Platinum points attention.
          - Broken brushes
          - Failure in cond
          - Internal shortin wet.
          - Failure of insul
          - Dirty contacts.
      - Faulty wiring

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External brakes are usually prov ided with an adjustment on the brake

band, which permits one to draw the ends of the band closer together and take up much of the lost motion between the band and the brake drum. After the brakes are adjusted, it is well to jack up the machine to make sure that the wheel turns freely and that there is no binding between the brake members and the drum on the hub. If the brake is adjusted too tightly the friction will cause heat after the motorcycle has been run a short distance, and this increase in temperature is a very good indication of power loss by friction between the brake and the drum. If the brakes are not adjusted sufficiently tight, a full movement of the pedal or hand lever will prove inadequate to apply the brakes tight enough to stop rotation of the wheels. When the friction facing is worn, it must be renewed. Slipping of metal-to-metal brakes is often due to accumulation of gum or old oil. This is a common fault with multiple disc types. If a disc brake heats up, the surfaces of the plates are rough and do not pass each other freely.

Repairing Inner Tube Punctures.—The first thing to do is to locate the hole through which the air is escaping. If it has been caused by a nail or other large object, it may be easily found by examining the tube, but in some cases it may be a very small puncture that cannot be discovered readily. After removing the inner tube blow it up until it is distended to its normal size. Do not put enough air in the tube to stretch it as if the pressure is too high it may enlarge the hole. If a bucket or trough of water is at hand, immerse the tube in the water a little at a time, at the same time slightly stretching the tube. If this is done carefully, air bubbles will be seen rising from the leak, no matter how minute it is when the injured portion of the tube is under water. If it is impossible to get enough water to immerse the tube, dampen the hand and pass it along the tube surface. The wet hand is very sensitive to even the slightest air current, and the leak can be found very readily in this manner. Another way to locate a leak is to blow the tube up and then pass it close to the ear, revolving it slowly so that all parts of the tube are passed before it. The leak will be evidenced by a hissing noise which is in proportion to the size of the leak. A good way of marking the leak positively is by means of an indelible pencil which will leave a mark on the rubber when moistened that will not come off.

A piece of sandpaper or emery cloth is usually provided in a repair

kit, and with this all of the gray deposit from the rubber should be cleared from an area around the puncture, somewhat larger than the patch to be fitted. This talc and powdered rubber may also be washed off with gasoline or scraped off with the blade of a jack-knife if the sandpaper is not available. It will be well to treat the surface of the patch in the same manner, and to roughen up the clean surfaces of both tube and patch with sandpaper or a wire scratch brush. A light coat of cement is then applied to both patch and inner tube, and

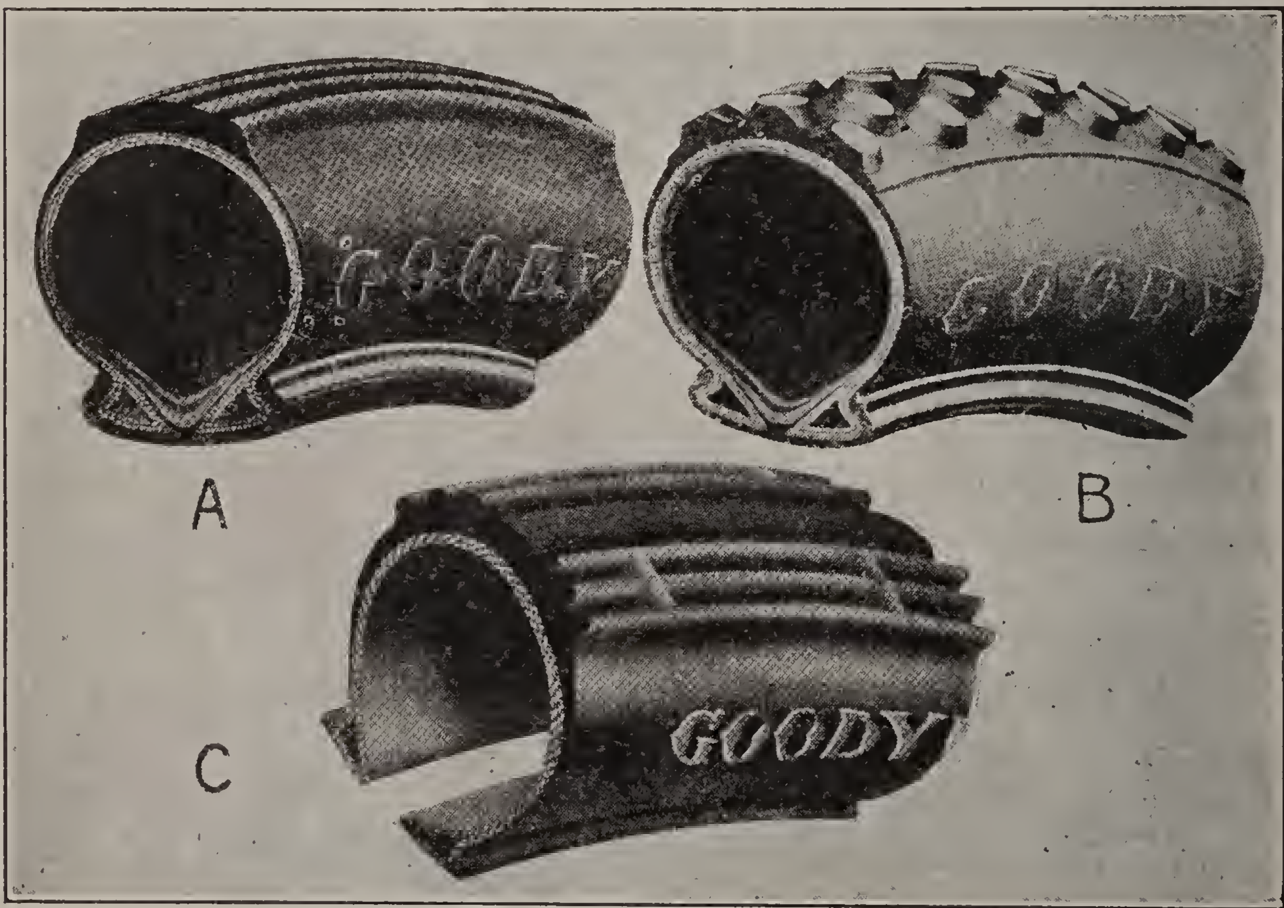

Fig. 336.—Conventional Forms of Motorcycle Outer Casings That Have Been Generally Applied. A—Corrugated Tread. B—Studded Tread. C—Combination Tread.

is allowed to dry for five or six minutes. Then the operation is repeated and more cement is spread over the surface. This is also allowed to dry, and, when the surface is sticky, the patch is pressed firmly in place and held in position by a clamp or some other means that will produce pressure. The patch should be allowed to set for ten or fifteen minutes before replacing the tube. Powder the patch and tube freely with soapstone or talc to prevent the tube sticking to the casing.

It is well to examine the casing before replacing the tube to be sure that the cause of the puncture is removed. This may be done by passing the hand around on the inside. The puncturing object often becomes imbedded in the rubber, and while it is not visible from the outside it may stick through the casing and protrude on the under side. Temporary repairs to the casing should be made from the inside. A piece of fabric three or four times the width of the hole and long enough to reach from edge to edge of the casing should be cemented in place. This is done by cleaning the lining of the casing and applying two coats of cement, while the prepared fabric which is already coated with rubber should be wet with a little gasoline before it is pressed in place in the inside of the shoe.

Outer Casing Repairs.—If a tire, even when well inflated, strikes a sharp stone at high speed this is apt to tear off a portion of the tread, and often injures several plies of the fabric. This is called a stone bruise and weakens the shoe to some extent, depending upon the amount of material removed from the casing or the depth of penetration and its location. The shoe is weakened much more if the tread is damaged than if the side wall is scraped. If a stone bruise or other cut penetrating the tread is neglected, sand or road gravel is apt to work into the tire as it revolves and this material soon accumulates between the tread and fabric or between the layers of fabric until it forms a protuberance of some size. This is called a sand blister. The action of this compacted material is to break down the layers of fabric between it and the tube and the casing inevitably, blows out if the defective condition is not remedied.

Rim cutting is usually caused by running the tire flat or not inflated sufficiently. It is sometimes due to rusty or rough rim edges or to poorly fitting rims or improperly designed beads on the tire casing.

Cuts in casings allow water to enter and rot the fabric even if they are not sufficiently large to weaken the shoe appreciably. They may be easily filled up by using special repair pliers to spread out the rubber and open the cut sufficiently to clean it out with gasoline and insert special cement and repair gum. When the pliers are withdrawn, the rubber closes around the repair material, and when the gum hardens it fills the hole thoroughly.

Weakened casings can be used for some time by the insertion of

a reliner of fabric which strengthens it and presents a solid, unbroken surface for the inner tube to bear against. An outer casing or leather protector may also be employed.

A good temporary repair of a burst casing can be made by using an inside and an outside blowout patch. A new inner tube should never be inserted in a burst casing without first taking some precautions to close the hole or rent, both from inside and outside, or the tube will blow through at the weakened spot of the shoe before it has been in use for any length of time. The inner patch is composed of several layers of frictioned fabric (fabric impregnated with rubber compound) and the larger sizes are provided with hooks which engage the rim if a clincher type is used. It is from six to eight inches long

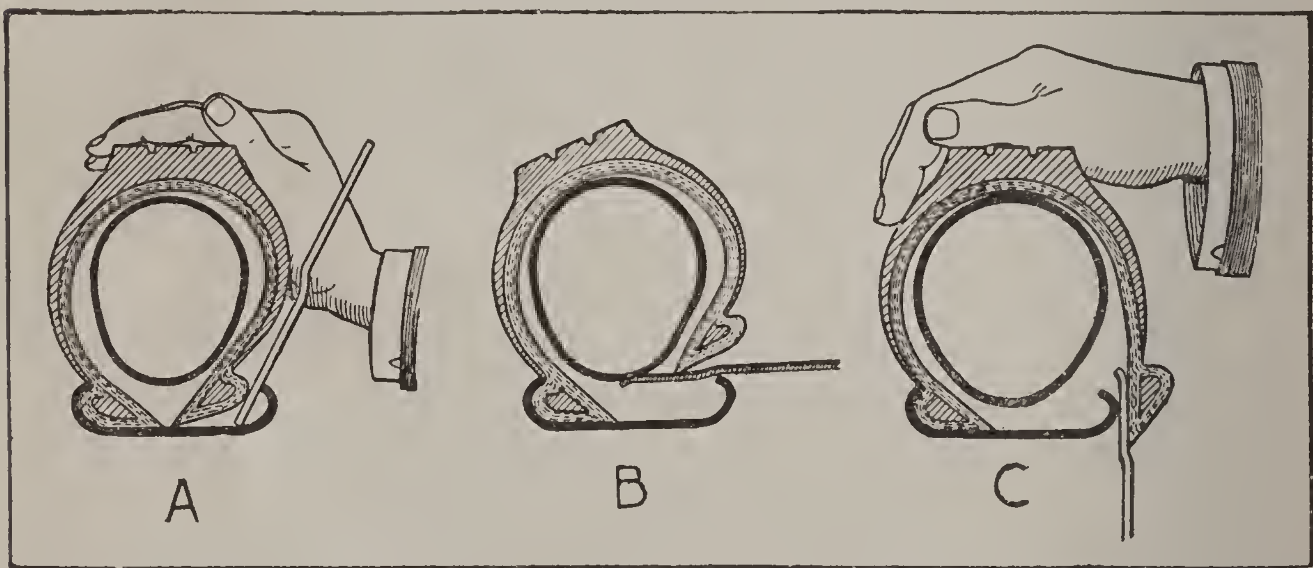

Fig. 337.—How to Remove Motorcycle Tire Outer Casing Without Pinching Inner Tube.

for small tires. The strength of fabric used also varies with the size of the tire the patch is made for. This is placed in the casing in such a way that the rent comes at a point approximately at the center before the inner tube is inserted. After the casing is replaced and is partially inflated, the outer shoe or patch is laced tightly in place around tire and wheel rim and then inflation of the tire is completed. A repair made in this manner is reliable enough so the tire remains in service for some time without attention, though the temporary patches should be replaced by a permanent repair at the earliest opportunity. Winding the casing with tire tape will help if no blowout patch is available.

To repair a badly cut or rent outer casing, it is usually necessary to rebuild the casing at the injured part. The injured fabric is cut out and replaced with new, and new tread rubber is also applied to the outside of the casing. The layers of fabric or rubber are well cemented with special material adapted for curing, and are thoroughly vulcanized together and amalgamated with the remainder of the shoe. In cutting out the old fabric, the first inside layer is cut out at least six inches each side of the blowout. The next layer is stripped off for

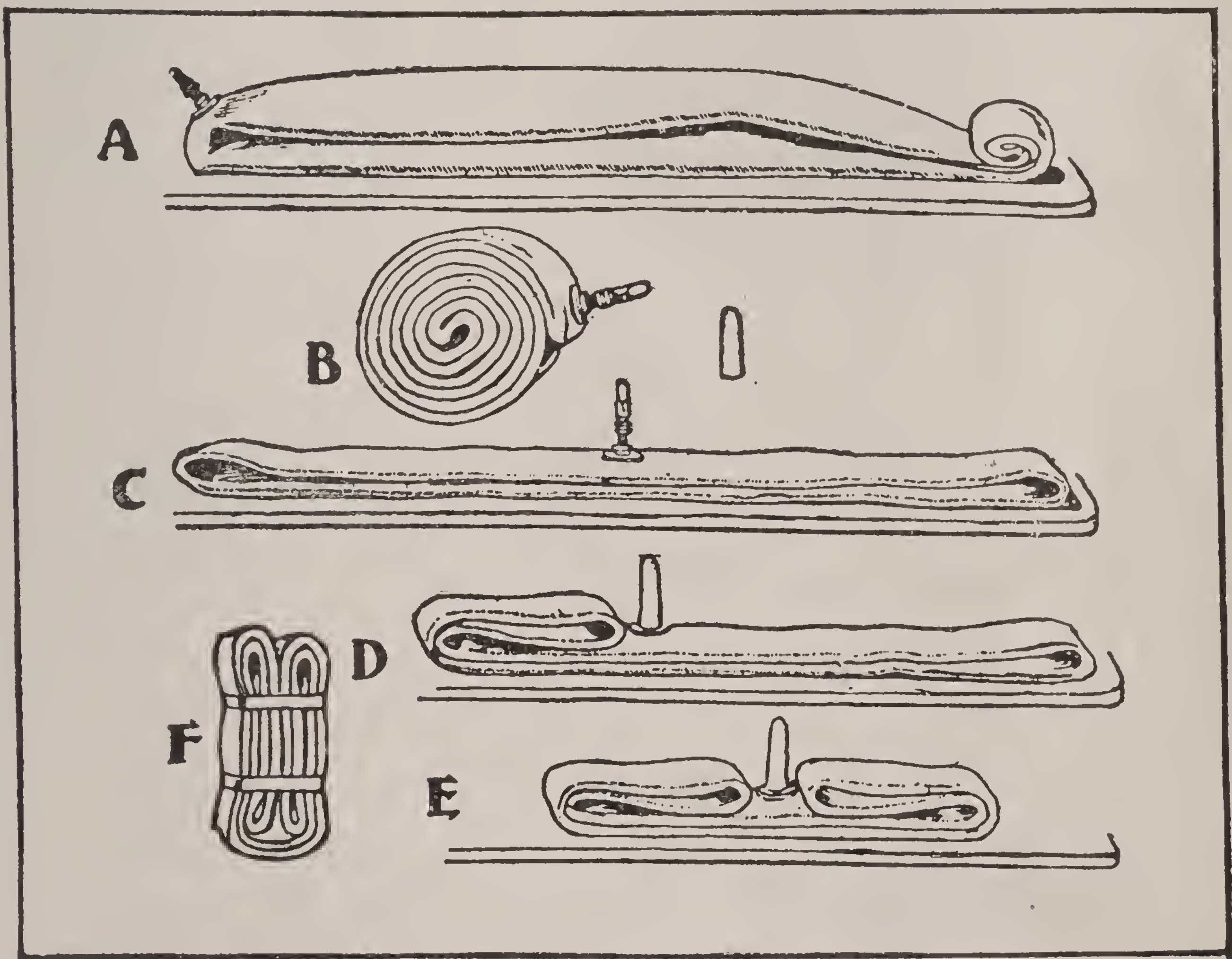

Fig. 338.—Defining Methods of Folding Inner Tubes for Transportation.

five inches each side of rent, then two or three of the succeeding layers are taken off for the same distance say four inches each side of the injury. In replacing the layers with new fabric, it is cut to fit the steps left when the injured material has been removed. Building up in this manner makes a much stronger repair than just replacing the injured material would, because each layer applied reinforces the others beneath it, and when the last ply is in place and all firmly

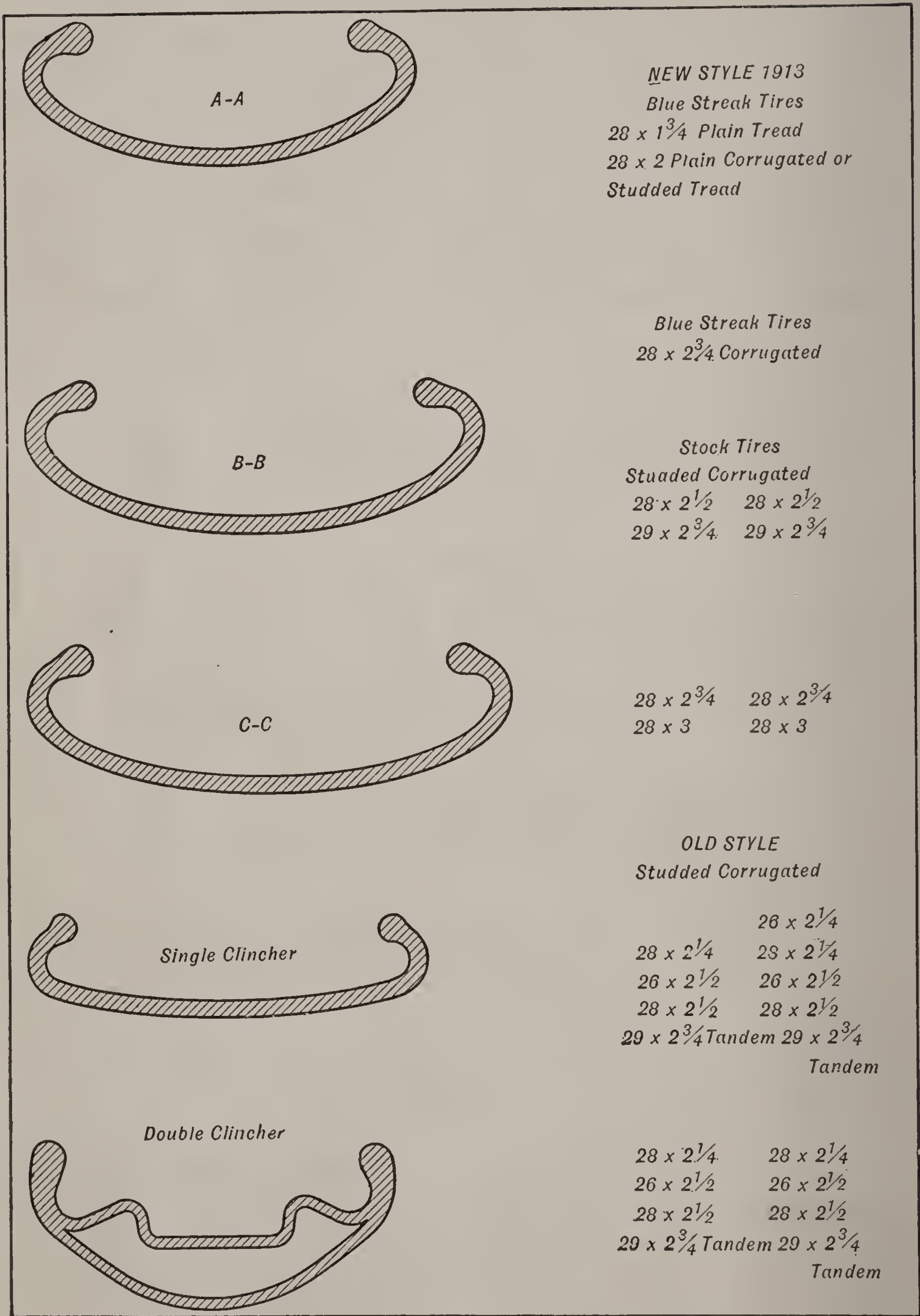

Fig. 339.—Showing Forms of Rims That Have Been Used in Motorcycle Wheel Construction and Sizes of Tires Adapted for Them.

joined together by the curing process, the shoe is practically as good as a new one.

Improper inflation is responsible for much of the tire trouble that comes to motorcyclists. Under-inflation makes rim-cutting easy. The continued flexing of partially filled tires tends to break down the fabric in the side walls. Careful, scientific tests—trials of actual service—have shown conclusively the air pressure best suited for each tire size. The following table is offered by the Goodyear Company:

Regular Tires.	Racing Tires.
2¼ inches, 30 pounds	1¾ inches, 45 pounds when cool
2½ inches, 32 pounds	2 inches, 50 pounds when cool
2¾ inches, 35 pounds	2¼ inches, 55 pounds when cool
3 inches, 40 pounds	

Advice to Purchasers of Second-Hand Motorcycles.—In the present state of efficiency of motorcycle manufacture, no machine can be said to be worn out for several years, but styles change very rapidly and there will always be those who want to be right up to the minute regardless of the expense entailed. In consequence, there is on the market to-day a large number of excellent second-hand machines. But in no other business, except perhaps the gold-brick and green-goods line, is it so easy for the novice to make a poor bargain. It is very difficult to tell the real condition of a motorcycle at a glance, and even a trial cannot always be depended on. Furthermore, a machine may run nicely for a few miles, and yet, in a few weeks, require endless repairing. On the other hand, one often finds motors which, through bad handling or lack of tuning, run very badly or not at all, though for a small outlay of time and money, properly applied, they could be made to give excellent results.

The first thing to consider is whether the machine in question is worth purchasing at all. With the large selection offered one can afford to be particular; there are some faults which it is not worth while to attempt to remedy. The question of age resolves itself entirely into a question of make, for, if the machine was a good one in the beginning, it will be good much longer than one which was originally of a lower grade; but the matter of design is also important. Be sure its maker is still in business. A machine of short wheel-base,

high saddle, high-hung engine, and short handle-bars will never be comfortable, and it would be wiser to wait for an opportunity to obtain one of a more modern build. Transmission must also be considered. The type is entirely a matter of personal preference; but block chains, roller chains too small for their work, a narrow flat belt with an idler, "V" pulleys not cut to twenty-eight degrees, or too small an engine pulley, can never be made to give efficient service. A cracked frame lug, cylinder, crank-case, or piston, or a buckled wheel, also mean repairs that had better be left for the buyer with mechanical skill.

Not less important is the condition of the engine. This is the heart of the machine, and, if it has been seriously injured, the cycle will be part of the repair shop furniture for some time to come. Jack up the rear wheel, and stand on the pedal with the exhaust valve dropped. A high compression engine in good condition will hold your weight almost indefinitely in this manner, but if the pedal does not fall for several seconds, the cylinder and rings may be considered to be in good condition. If it goes down rapidly, the engine should be examined further. Have the cylinder taken off and run your finger carefully all over the inside surface. If you find any cuts, scratches, grooves, or rough spots, it must be replaced. If, however, it is all bright and smooth, you may turn your attention to the rings. Examine carefully the surface which rubs against the cylinder. It should be all brightly polished, but there will probably be dark spots. If these spots are very frequent, you had better steer clear, but if only a few it simply means new rings. First, however, be sure that you can obtain new rings for that particular make of model, as it is an expensive job to have them especially made.

While you have the cylinder off, glance at the bearings. Run off the belt or remove the chain and try to move the pulley or engine sprocket up and down. A tiny amount of play is to be expected here, but if it is at all great, new main bushings will be needed, the cost of which must be added to the price you are to pay. The same is true of the crank and wrist-pin bushings. The former can be tested by moving the connecting-rod up and down while the pulley is held still, and the latter by holding the connecting-rod with one hand and moving the piston up and down with the other. If the motor is a

ball bearing form and the bearings are worn, remember that these cost money, in fact, several times as much as plain bearings. Better let someone else buy them.

Next to motor repairs the tires are probably the most expensive parts to renew. These are often overlooked in buying a second-hand mount, because they can be obtained anywhere, but it should be remembered that they cost a great deal. A flat tire means a puncture or rotten tube, although the owner may tell you that he just let it down "to keep it from stretching." Chains or belts are also large items and their condition should be noted. Do not forget to examine the sprockets, as, if they are worn, it will be useless to replace the chains unless they are replaced also. Damaged pedaling gear, broken brake, dented tanks or rims, run-down batteries, bent spokes, and broken mud-guard stays or control levers, are of less importance, as they are easily repaired, but they should all be looked for and taken into consideration.

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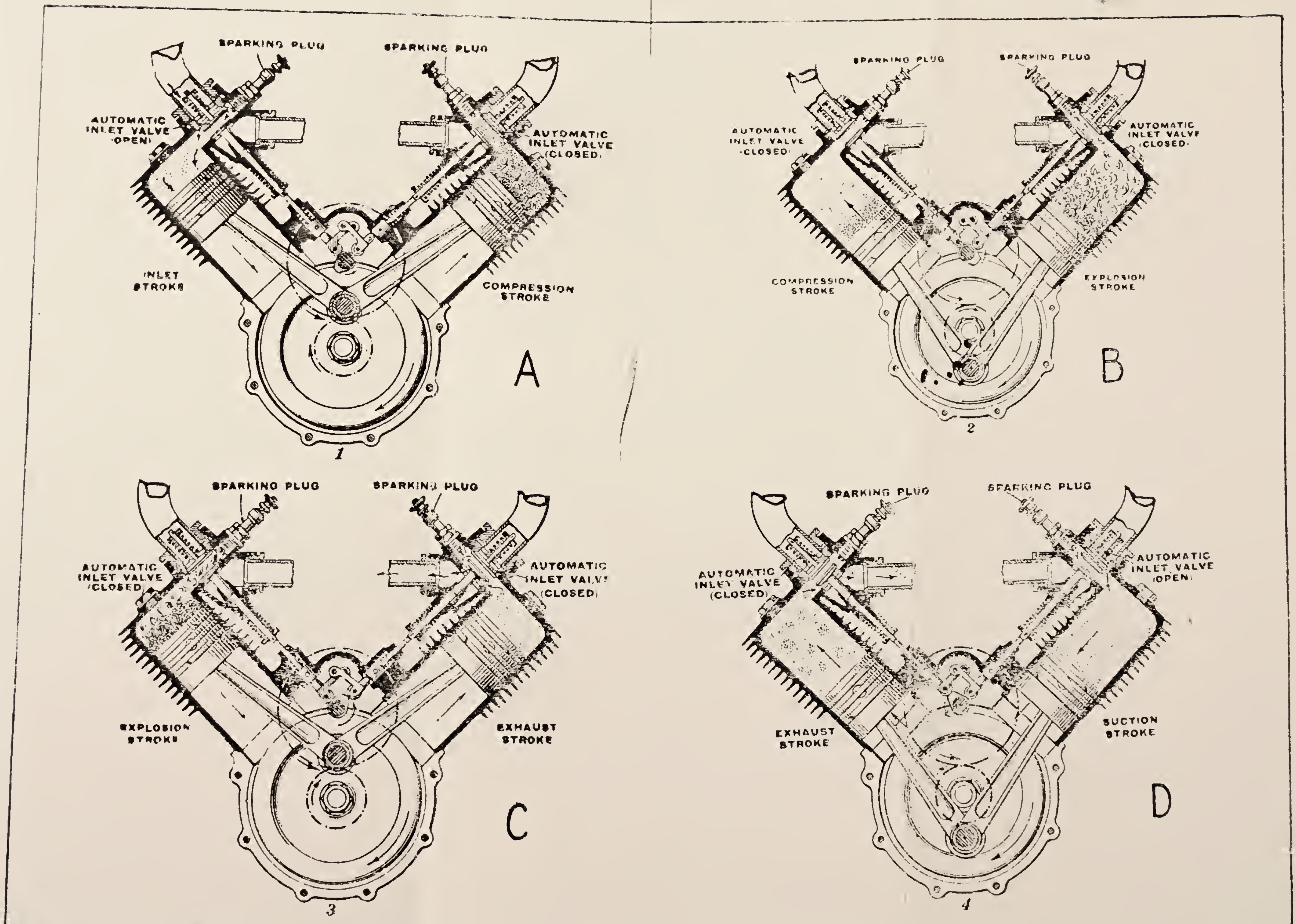

Fig. 44.—Diagram Showing Action of Twin Cylinder, Four-cycle Motor.